A Practical Course in Mechanical Drawing

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For Individual Study and Shop Classes, Trade and High Schools

BY

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With 131 Illustrations, a Reference Vocabulary and Definitions of Symbols

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CONTENTS

THE attention of the student is called to the *Reference Glossary* and also to the *Definitions of Symbols* which are printed near the end of this volume. A careful reading at first and occasional reference to these pages as the study progresses will be found of great assistance.

PRACTICAL MECHANICAL DRAWING

CHAPTER I

INTRODUCTION

MECHANICAL drawing is one of the most popular and most profitable subjects of study for the boy or young man of today. It is an essential qualification in most lines of engineering, an almost indispensable accomplishment in many occupations, and often the secret of successful advancement. It is founded upon the science of geometry, which, as applied to drawing, becomes a delightful and interesting subject, and not the difficult study the beginner fears. For illustration, a farmer wishes to know how many gallons of water will fill a tank, the diameter and height being known; how many bushels of wheat will fill a bin, or how many acres there are in a field a quarter of a mile square. These examples, like many others, illustrate the practical application of geometry, a subject no less important to the mechanic than the farmer, but a thousand times more interesting to the student than the usual text book.

In preparing this manual the author was ever mindful of the many circumstances and limitations which have so often combined to deny to aspiring youth the advantages of a complete education. In this day and age competition and industrial conditions demand the best training and skill for every productive effort. What the artisan or mechanic does to improve himself

intellectually, to this end, increases his efficiency and value to his employer in every respect.

In geometry a student is concerned with the theorem of a problem, and the proof, or why it is so. In mechanical drawing the mechanical operations of construction—the actual doing of a problem, graphically, by the use of compass, triangles and other instruments—is considered essential and sufficient. However, this course does not preclude a master's knowledge of the principles of geometry. Any live, wide-awake boy can apply, to a good advantage, these geometric exercises to some project which he desires to work out or invent, without first having studied the subject.

The surveyor with his tape and transit, the architect or mechanical engineer with his slide rules and formulas, must know these exercises also. If a craftsman desires a brace or bracket for a plate rail, he must know how to "lay out" the desired curves and angles. If a boy desires to make a taboret or jardiniere-stand with a hexagonal or octagonal top, he must *first* solve the geometric problem or consequently be unhappy with the results.

One reason for not accepting a freehand perspective sketch as a substitute for the geometric drawing lies in the fact that the sketch seldom shows all the information required for the workman. The sketch deals with outward appearances only and from one viewpoint. The mechanical drawing of an object delineates the actual facts, within or without, and from as many viewpoints as the object has dimensions. Any hidden or detailed information is considered as important as that which is visible, and these details are represented accordingly by suitable conventions, the word convention,

in drafting, meaning a customary symbol or method established by precedent.

The freehand sketch is governed by well-known laws of perspective which constitute the language of the artist from the esthetic standpoint. The mechanical drawing is represented by customary shop and drafting-room conventions and is the language of the mechanic and artisan. The one develops the power of observation, good judgment and individuality; the other, precision, accuracy and mechanical ability.

An advantage that the mechanical drawing has over the sketch is that the workman will not be apt to confuse *apparent* dimensions, as seen from the perspective, with true measurements, as seen from the workman's drawing. All working drawings are made to scale, and all dimensions are proportional and properly placed. They must be made in such a manner that the "dumbest" man in the shop will understand them. Otherwise, if an error occurs in construction, the blame attaches to the draftsman. Such a drawing must keep in mind all those who must, of necessity, use it. Mechanics, designers, engineers and artisans of any trade fully realize the importance of a definite plan of procedure. Bridges, buildings, railroads and canals must be thought out on paper, and their feasibility satisfactorily passed upon, before a mechanic or construction company begins the actual work. Perhaps the most important part, if not the most difficult, is the making of the plans and specifications. The next most important part is working according to the direction of the plans.

Constructive drawing also finds expression in a multitude of shops. A cabinetmaker, machinist, patternmaker, or contractor, must have intelligent pictures or

drawings to guide his hands, and these drawings must be accurate and clear. A draftsman, whether amateur or professional, who fails to make them so, may, through ignorance and carelessness, or both, cause a loss of great consequence to his employer and the world at large. Someone has said: "Mechanical drawing is the alphabet of the engineer; without it he is only a hand. With it he indicates the possession of a head." It is needless to say that the hand will only do what the head directs.

A uniform code of conventions and symbols is required among workmen and shops just as among telegraph operators. Such a language, if it may be so called, has come to be accepted generally among draftsmen who adhere closely to the modern approved forms, and these will be used throughout this manual.

CHAPTER II

THE DRAFTSMAN'S EQUIPMENT.

THE old saying that a poor workman blames his tools is very nearly if not always true, for if a workman is content to work with an instrument poor in quality or poorly kept, it must be taken that he expects to do poor work. How can a draftsman produce an accurate drawing if the compass legs are not firm and the points blunt, T square nicked, triangles warped, pencil dull, ruling-pen clogged with ink, and many other possible imperfections which would mar the finished drawing? Hence, it goes without saying that to do commendable work one must have good materials, take excellent care of them and keep them in perfect repair. A complete list is appended below, though not all are required. Those marked with stars are essential; the others are luxuries:

**Drawing-Board*—16x21 in., inlaid, can be made of A No. 1 soft white pine by mortising narrow strips across each end of the board. The size is not arbitrary. Local conditions may require smaller boards and thus, of course, smaller plates. Fig. 1.

**Drawing-Paper*—Whatman's hot or cold-pressed (white) paper. Keuffel & Esser or E. Dietzgen cream paper, size 12x16 in. or 15x20 in.; but size of board and paper to be determined by local conditions, per above. A good bond paper may also be used. Two-ply bristol paper is excellent. For Patent Office drawings three-ply bristol paper is required.

**Thumb-tacks*—Comet No. 2 is one of many good tacks. They come in small tin cartons.

**Pencils*—2H and 4H. Sharpen so that the lead is exposed $\frac{5}{16}$ or $\frac{3}{8}$ in.

**Erasers*—Faber No. 211, Art Gum, Eberhard typewriter ink eraser, or others as good.

**Scale*—Ordinary hardwood rulers will do at first. A triangular boxwood scale, divided into different scales, is best.

**T Square*—Should be as long as the board and made of pear wood. Boys can make this in the wood shop. Fig. 1.

**Triangles*—30-60-90 celluloid, 8 in. or 10 in. long, 45-90, celluloid, 6 or 8 in. long. Wooden triangles are inaccurate. Fig. 1.

Emery Pad—Or No. 000 sand-paper, to sharpen pencils. Each pencil should be sharpened chisel-shaped at one end and conical at the other. Use a 2H or 4H-grade.

**French Curve*—Celluloid. Lead curves are cumbersome and expensive.

Case or set of Instruments—Containing:

*1 compass with lead and pen adjustment and lengthening bar.

1 divider (large).

1 divider (bowspring) 3 in. long.

*1 ruling-pen (large).

1 ruling-pen (small).

1 bowspring compass (ink).

1 bowspring compass (pencil).

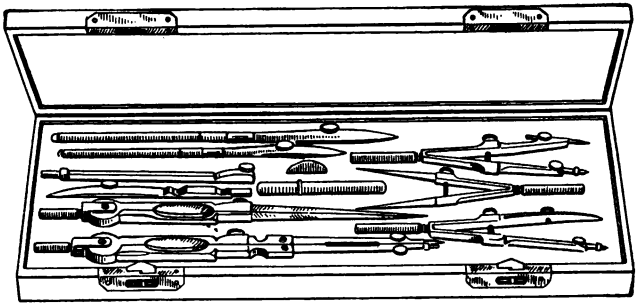
1 box leads.

1 protractor (German make preferable).

1 penholder and pen, No. 506 and No. 516, ball-pointed.

*1 bottle Higgins' water-proof ink (black).
1 typewriter erasing-shield (celluloid or nickel-plated).

These instruments, including the paper, need not be expensive, *i. e.*, those marked with stars. Cheap brass sets are worse than useless. If it is convenient, the purchaser should consult with a practical draftsman before selecting the materials.



Case of Instruments

HOW TO USE THE MATERIALS

1. The paper should be tacked in the upper left-hand corner of the drawing-board so that the T square may not slip when drawing the lowest lines on the plate.
2. Thumb-tacks should not be withdrawn by the fingers. Use a knife blade or other flat instrument.
3. To get clean, sharp lines, pencils should be sharpened frequently, but under no circumstances must ridges be made on the drawing by heavy pressure on the pencil.

4. Use a soft gum eraser to clean the drawing before inking, that a glossy finish to black lines may be retained. Use ink-erasers for pencil lines only in exceptional cases where the pencil has caused deep ridges in the paper. All division lines should be erased before inking.

5. All dimensions should be stepped off from the scale or ruler, with dividers, and then pricked lightly in the required place on the drawing. Explanation will be given later as to how to scale a drawing properly.

6. Always use the *upper* edge of the T square, which should be held against the left-hand edge of the drawing-board. Never use the upper edge of the square as a cutting edge. The least nick will cause inaccurate work as long as it is used thereafter. Fig. 1.

7. The triangles, which are used to draw oblique and perpendicular lines, should rest upon the upper edge of the T square. Many and various combinations of angles may easily be made by combining both the 30-60 and 45-90. The oblique side of the triangle should always be to the right while in use, whether in inking or penciling. Fig. 1.

8. The celluloid irregular curve is used in defining curves which are impossible to obtain with the compass. It is composed of many curves, but has seldom the right one, so that it is often necessary to shift it into many positions before required results may be obtained.

9. Only two instruments in the case need explanation, and this is better acquired by practice. The *compass* legs are jointed so that the nibs of the pen may be square to the surface of the paper while the circle is being drawn. The hand should describe the circle above the paper while in operation, and not remain sta-

tionary. The *ruling-pen* should incline slightly in the direction of the line and should be held so that the nibs of the pen are not in contact with the edge of the T square. To keep the instruments from corroding, polish them with a small chamois skin and five cents' worth of chalk precipitate, or Spanish whiting. Instru-

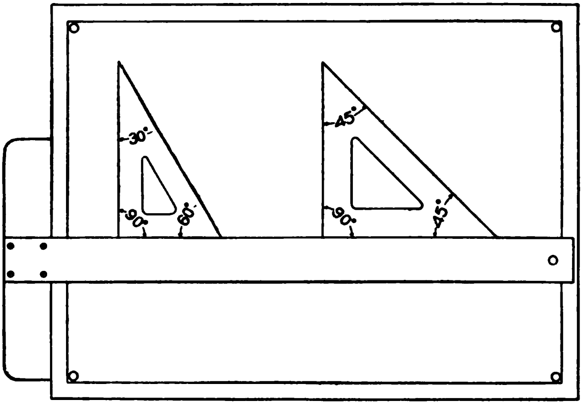


Fig. 1

ment must be kept clean. A thin piece of linen should be drawn between the nibs of the pen after each using, as the air congeals the ink quickly. The pen is filled by dropping the ink from the quill,—which is in the stopper of the bottle,—while being held in a vertical position. It should never be filled over one-quarter inch. Lines are ruled from left to right and bottom upward. Use the adjusting screw to get the desired width.

10. The German protractor is a semi-circular instrument graduated into 180 degrees. This is used to obtain angles other than those obtained by the triangles.

11. Higgins' inks are waterproof. Should a blot occur, first erase with the ink eraser. (Never use a knife.) Second, glaze the roughened surface by using the back of a bonehandled knife, or soapstone. Third. "size" the glazed surface by spreading over it a thin coat of graphite, from a soft pencil. The paper is now ready to re-ink.

CHAPTER III

GEOMETRIC EXERCISES WITH INSTRUMENTS

EXERCISE 1.—Bisect a line of any length and arc of suitable radius. Construction: With radius greater than one-half of AB and points A and B as centers describe intersecting arcs at 1 and 2. If a line be drawn from 1 to 2 it will bisect AB. Fig. 2.

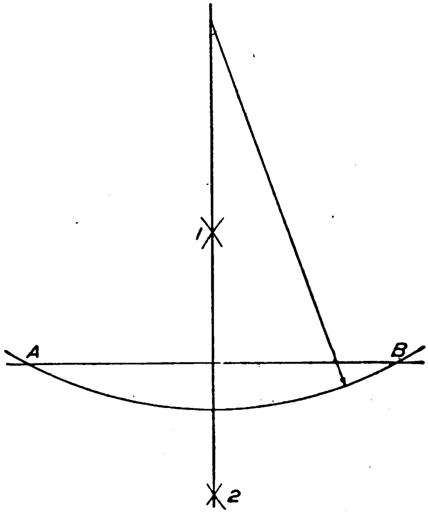


Fig. 2

Exercise 2.—Erect a perpendicular to a given line (Problem 1.) Fig. 2. Second method. Construction: From a given point E outside the given line AB draw a line at any angle to AB. Bisect and inscribe a circle

about CD. Where the circle cuts AB is a point of the ⊥ through point E. Figs. 2 and 3.

Exercise 3.—To draw a // line through a given point X to a given line AB. Construction: From any point

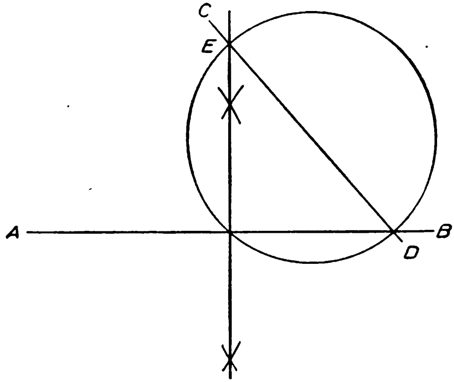


Fig. 3

A on the given line and a radius equal to AX describe arc. From X and any radius describe a similar arc through B. Lay off BY on second arc = to AX. A line drawn through X and Y is // to AB. Fig. 4.

Second method. Construction: Draw a line making any angle with AB. With C as center and any radius

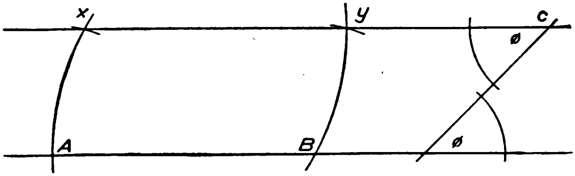


Fig. 4

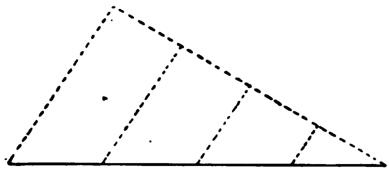


Fig. 5

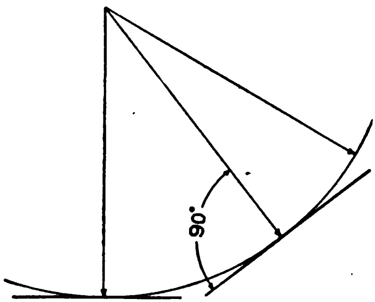


Fig. 6

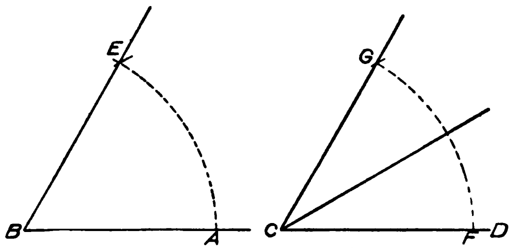


Fig. 7

describe an arc making angle Ø. Duplicate this angle with given point as center. Fig. 4.

Exercise 4.—Divide two lines into proportional parts. Construction: Lay off one line into any number of divisions. Connect the extremities of each line. By means of triangles draw parallels through remaining points. Fig. 5.

Exercise 5.—Construct tangents to a given arc of

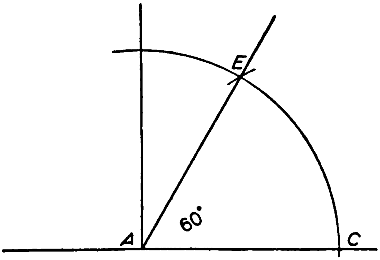


Fig. 8

any radius. Construction: With any radius describe arc of a circle. From the center of the arc to any point of the circumference draw a radial line. At the extremity of the radial on the circumference erect a ⊥. This is the required tangent. Fig. 6.

Exercise 6.—Duplicate and bisect a given angle. Construction: Draw any two intersecting lines, making any convenient angle. To duplicate, draw CD with any length. Describe an arc cutting given angle at A and E. With same radius describe arc cutting CD at F. Lay off, with F as center, the distance AE, and draw the other side of angle through C and G. Bisect as in Exercise 1. Fig. 7.

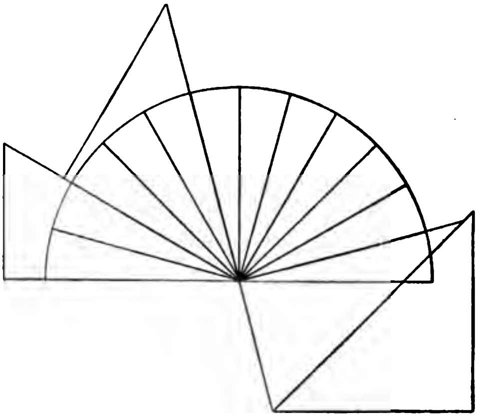


Fig. 9

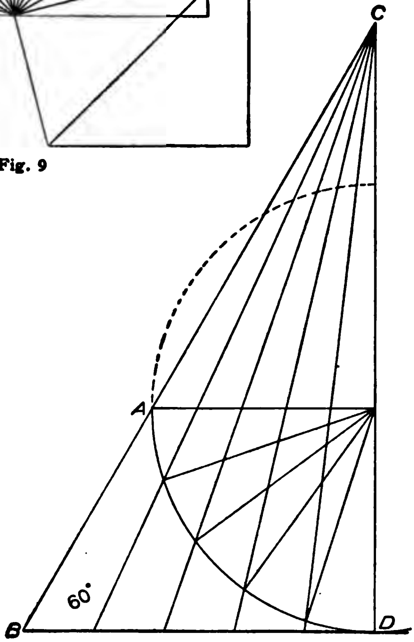


Fig. 10

Exercise 7.—To draw angle of 60°. Construction: With any line as a base and any point therein as a center, describe an arc of any convenient radius, cutting the base line at C. With C as a center and radius AC describe arc at E. A line through AE is 60° to AB. Bisect to get angle of 30°. Other angles can be easily determined. 22° 30′ reads 22 degrees and 30 minutes or 22½ degrees. (Fig. 8.) The table is as follows:

60″ (seconds) = 1 minute (′).
60′ (minutes) = 1 degree (°).
360° (degrees) = 1 circle.

[Note the characters (′ and ″) used to designate minutes and seconds are used also to designate feet and inches. The context will, however, generally avoid confusion as to their meaning.]

Can any angle be trisected?

Exercise 8.—By triangles only, divide a semicircle into angles of 15°. Use T square as a base for the triangles. Fig. 9.

Exercise 9.—Rectify a quadrant of a circle. Approximate methods. Construction: Draw a circle of any suitable diameter and divide into quadrants. Draw a tangent of indefinite length at lower end of CD. Through A draw a line making 60° to this tangent. Where it cuts BD determines the length of the arc AD. Any smaller arc can be determined by extending, through C and the other end of the given arc, a line to BD. Fig. 10. Second method. Approximate. Fig. 11. AE = BD, Fig. 10.

Exercise 10.—Construct a right-angle triangle one angle of which is 30°. The sum of all angles of any triangle is 180°. If a right angle is 90°, what must the remaining angles be? This exercise is applicable as an

aid in determining the *pitch* or length of a rafter, when the *rise* and *run* are given. Pythagoras discovered the principle that the square of the rise + the square of the run equals the pitch squared: $X^2 + Y^2 = Z^2$. Fig. 12.

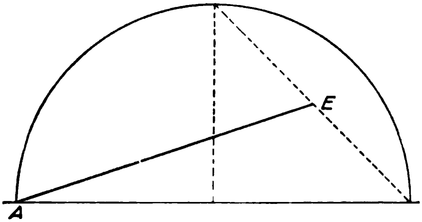


Fig. 11

Exercise 11.—To find approximately the distance across an unknown area by means of similar right angles. Construction: Select a tree or object on the opposite bank or side as indicated at A. Select another

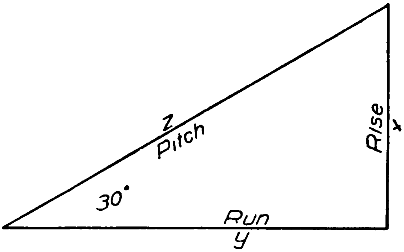


Fig. 12

on this side, say D. Lay off a convenient distance from D to C in the line ADC. Select a point B at right angles to AD and construct a parallelogram BODC. Determine point X on the ground which is in line with OC

and BA and measure the distance XO. By proportion,

$$AD : BD :: BO : XO \quad \therefore AD = \frac{BX \times BO}{XO}$$

Lay out the diagram, substituting known values for BD and DC and solve. Fig. 13.

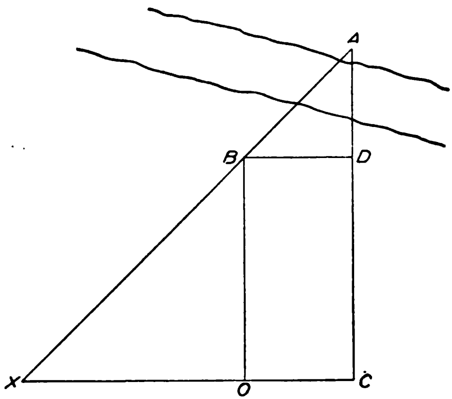


Fig. 13

Exercise 12.—Equilateral triangle. Construction: Assume any length for a base. With a radius equal to the length of base and each terminal C and D as centers describe intersection at X. Connect this point by lines to C and D. Measure the angles of an equilateral triangle in degrees. What is their sum? Stained-glass windows are often laid out in Gothic arch forms by this kind of triangle. Fig. 14.

Exercise 13.—Isosceles triangle. Construction: On a line of given or assumed lengths and with a radius

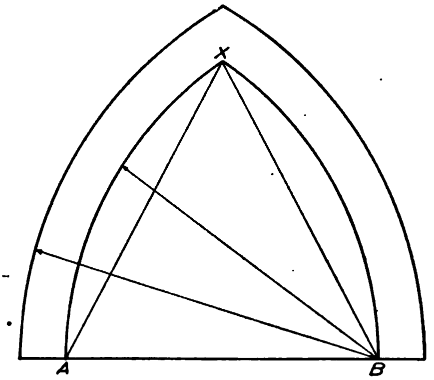


Fig. 14

greater or smaller than AB proceed as in the problem above. Are all the angles equal? What is their sum? Fig. 15.

Exercise 14.—The vertex angle of an isosceles triangle is 150°, and its base is 3 inches long. Without protractor make a drawing. The trilium is an early

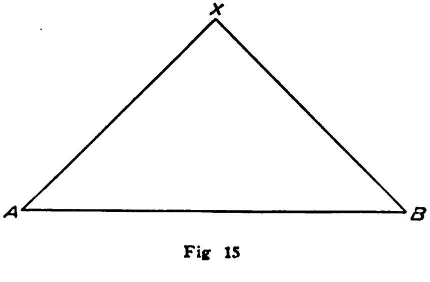


Fig 15

spring flower shaped on the order of an isosceles triangle.

Exercise 15.—Scalene triangle. Base 2½ inches, and base angles 22½° and 37½° respectively. What is the sum of the angles? Of any triangle? Fig. 16.

Exercise 16.—Inscribe a square within a 3 inch circle. Without. Fig. 17.

Exercise 17.—Circumscribe a square about the circle in the problem above. What is the relation of inner to outer square? The syringa is a four-petaled flower shaped like a square.

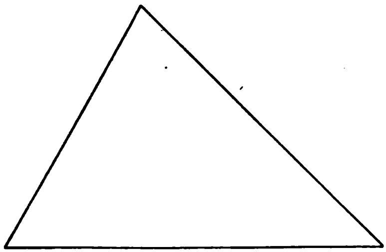


Fig. 16

Exercise 18.—Pentagon within a circle. Construction: Bisect the diameter of the circle. Bisect a radius. With C as center and AC as radius, describe arc at B. With A as a center and AB as a radius, describe arc on the given circle at D. AD is the length of one side of the polygon. Lay off remaining sides and draw a star. Fig. 18.

What is the size of an interior angle? Use protractor.

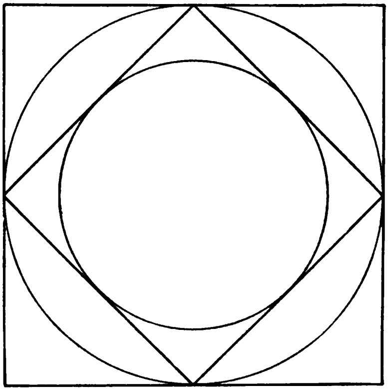


Fig. 17

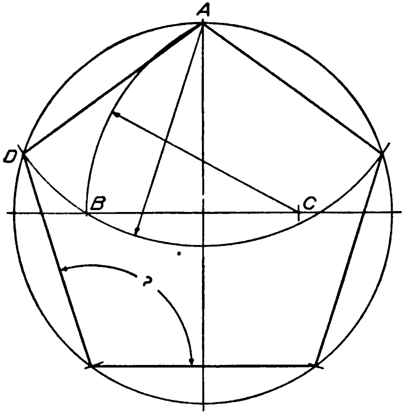


Fig. 18

Exercise 19.—Pentagon. Construction: Base 1¼-in. With one radius = to the base length describe arcs from centers 1, 2 and 3. Connect 1 and 2 with 7 and 8 and complete the pentagon. Inscribe a circle within

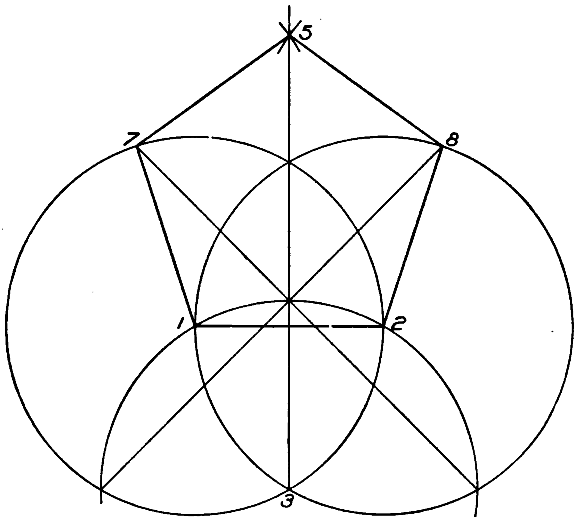


Fig. 19

the figure. Circumscribe a circle about the polygon. Many flower forms—pansy, violet—are pentagonal in shape. Fig. 19.

Exercise 20.—Hexagon. Within a circle. Construction: Lay off the radius six times on the circumference of the circle and connect the points. Without the protractor, what is the interior angle of this polygon?

Use this key: $2n - 4$ right angles when $n =$ the number of sides of the polygon.

$$\frac{(2 \times 6) - 4 \times 90^\circ}{n} = 120^\circ$$

Prove this to be true. Draw a six-pointed star. Fig. 20.

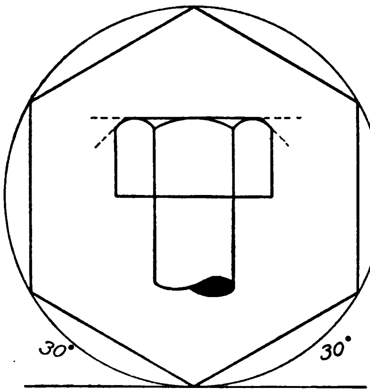


Fig. 20

Exercise 21.—Hexagon by means of the 30-60 triangle. The hexagonal bolt is an illustration of the use of the hexagon. Fig. 20.

Exercise 22.—Hexagon without a given circle. Fig. 21.

Exercise 23.—Heptagon within a circle. Construction. Draw a line making any angle with AB. Divide AB into as many equal divisions as the polygon has sides. With A and B as centers and AB as a radius

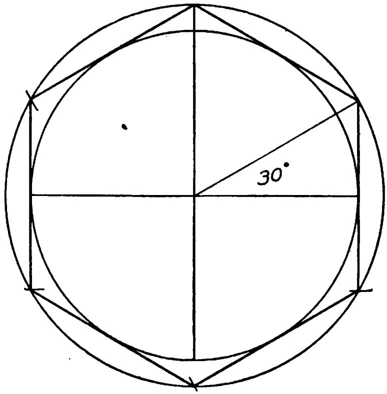


Fig. 21

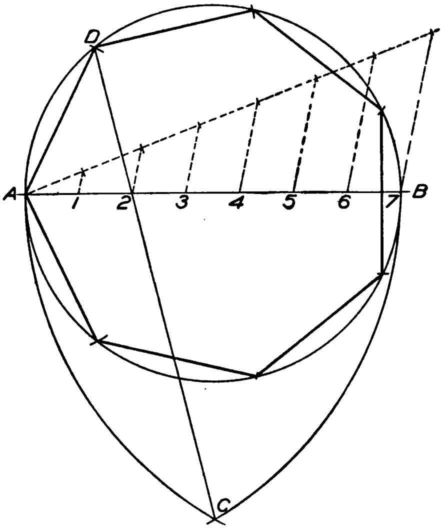


Fig. 22

describe arcs at C. A line drawn through C and 2, cutting the circle at D, determines the length of one side of the heptagon. This method will apply to any polygon. Use above formula to determine the size of the interior angle. Fig. 22.

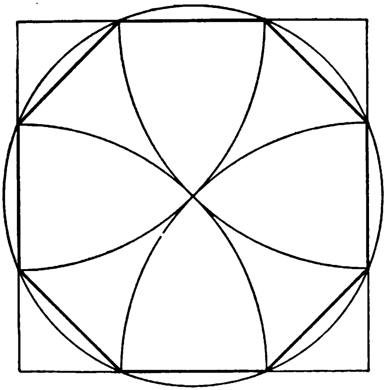


Fig. 23

Exercise 24.—Octagon within a circle. Construction: Within a circle of an assumed diameter, divided into quadrants, draw bisectors. The circumference is now divided into eight equal divisions. Determine and locate the size of the interior angle by the preceding formula. Fig. 23.

Exercise 25.—Octagon within a square. Fig. 23.

Exercise 26.—Combination of polygons on a given base of 1 inch. Construction: Proceed as in laying out a hexagon. Bisect the arc A-2. Trisect 2-B. With center 2, draw arcs cutting through C and D at 1 and 3.

Points 1 and 3 are centers of circles circumscribing polygons of the required number of sides. Fig. 24.

Exercise 27.—Inscribe circles about the triangles given in problems 10, 12, 13 and 15.

Exercise 28.—Inscribe three circles in the triangle given in Problem 12. Construction: Draw the medians of each side or bisect each interior angle. Bisect angle AC. Where the bisector cuts the line OX is the center for one circle. Fig. 25.

Exercise 29.—Five circles tangent to a given circle and each other; within or without the given circle. Construction: Divide the given circle into five equal parts and bisect each sector. The centers of each circle will be located on the bisector. Draw a tangent at the terminal of a bisector and extend it until it cuts a radial line. Bisect the angle this tangent makes with the radial and extend this bisector until it cuts AB at C; which is the center of one circle. Fig. 26.

Exercise 30.—A circle tangent to a given circle and a given line. Construction: With the radius of the required circle added to the radius of the given circle, and C as a center, strike an arc 1-2. Draw a line parallel to the given line with the distance = to the radius O of the required circle. Where this line and arc 1-2 intersect is the center E for the required circle. Fig. 27.

Exercise 31.—A shaft 1½ inches in diameter rotates within a ball-bearing consisting of 10 tempered steel balls. Make a drawing illustrating size of balls required. Fig. 28. Approximate. Construction: Proceed as in problem 29 except that the tangent circles are external to the given circle.

Exercise 32.—Four largest circles that can be drawn within a square.

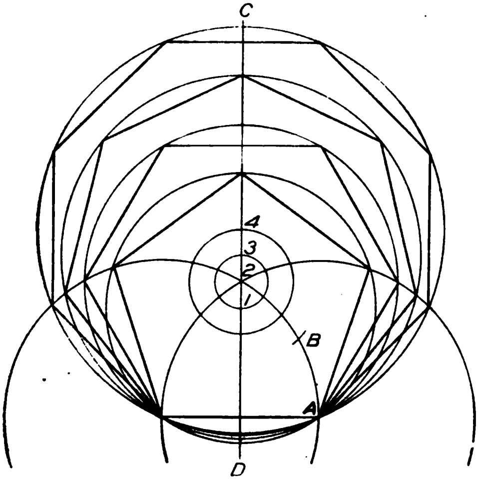


Fig. 24

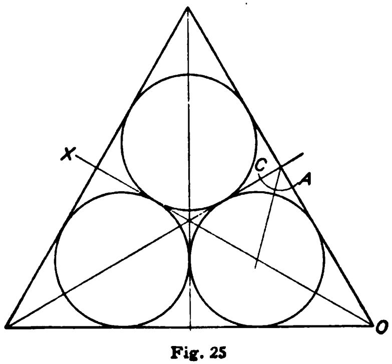


Fig. 25

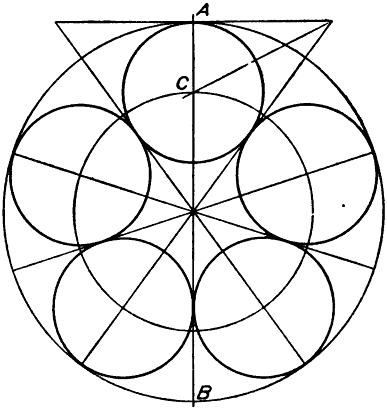


Fig. 26

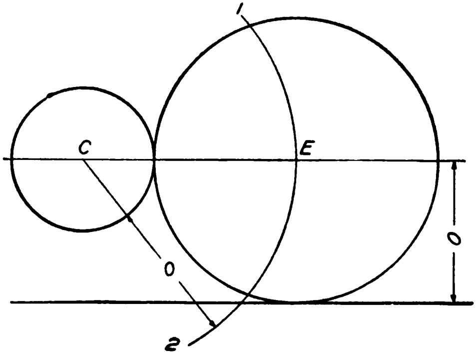


Fig. 27

Exercise 33.—A Maltese cross. Fig. 29. Construction: Draw two equal circles upon the two diameters of a given large circle and proceed as indicated in the drawing.

Exercise 34.—Draw a geometric border using the circle as a unit. Nearly all design is geometric in character. Fig. 30.

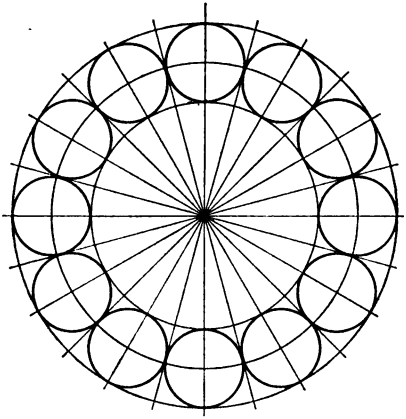


Fig. 28

Exercise 35.—Figure 31 is an original illustration of the Swastika.

Exercise 36.—Geometric monogram within a trefoil. Fig. 32.

Exercise 37.—Moldings. 1. Cyma Recta, Fig. 33. 2. Roman Ogee, Fig. 34. 3. Scotia, Fig. 35. 4. Echinus, Fig. 36. Ogee Arch, Fig. 37.

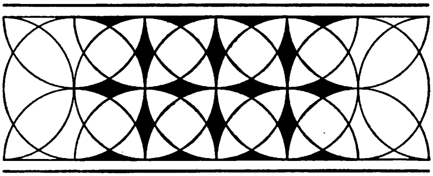


Fig. 30

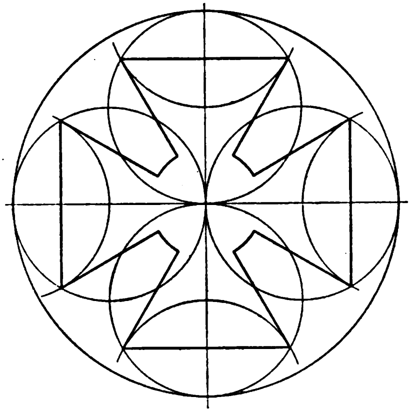


Fig. 29

Fig. 31

Fig. 32

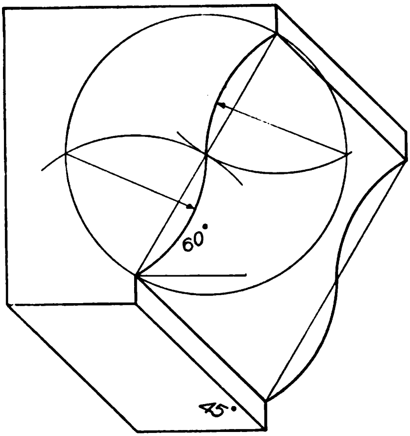


Fig. 33

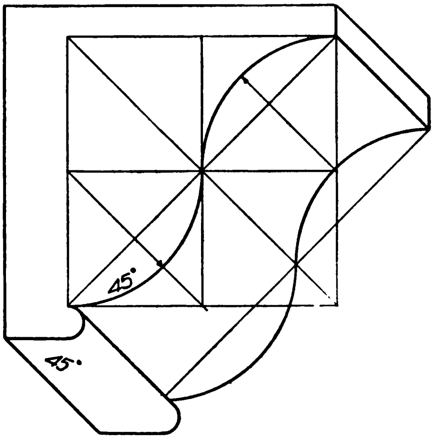


Fig. 34

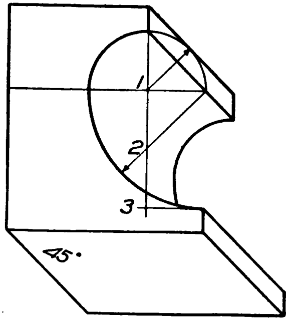


Fig. 35

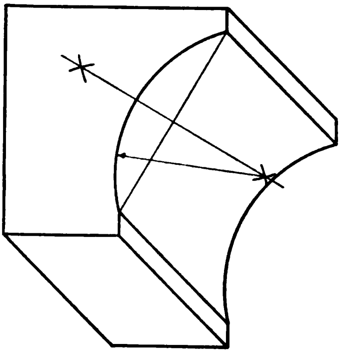


Fig. 36

Exercise 38.—The astronomer tells us that the plane of the earth's orbit is called the "ecliptic." This is an ellipse in shape. Draw an ellipse by two methods. The upper half to be constructed as follows: AC=4½ inches. DE = 3½ inches. DM = AB. M and F are centers of all arcs on the ellipse. From C as center lay off on BC any number of points, 1, 2, 3, 4, 5, etc. With C-1 as a radius and M and F as centers describe arcs.

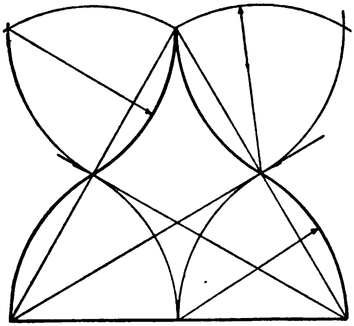


Fig. 37

With A-1 as a radius and MF as centers describe arcs intersecting C-1. These are points of the ellipse. Proceed until enough points are determined to locate the curve.

The lower half by the circle method is self-evident from the illustration. Fig. 38.

Exercise 39.—Trammel method. Fig. 39. Construction: Lay off on a small strip of cardboard the semi-minor and semi-major axes equal to the dimensions of the above problem. Move the point C so that it is always on the line AB and the point E on DF. By

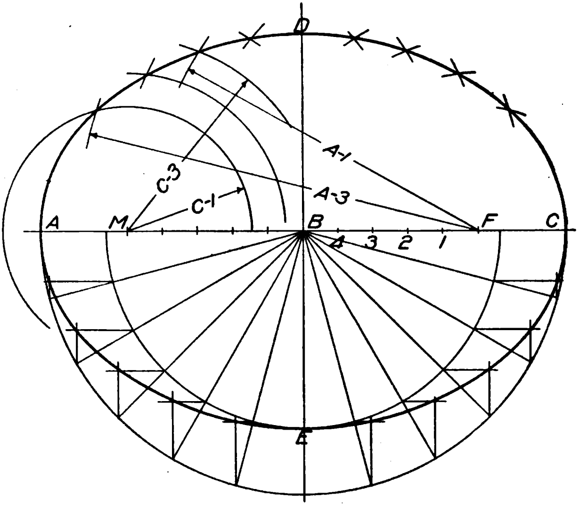


Fig. 38

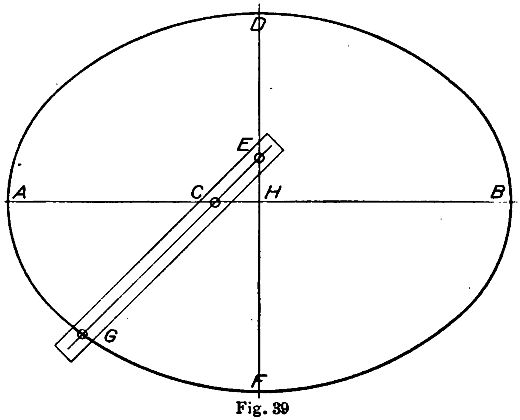


Fig. 39

changing the position of the trammel frequently, sufficient points can be located at G, on the trammel, to determine a symmetric ellipse. Make GC = DH and GE = AH.

Exercise 40.—Make a full-size drawing of the elliptic cam. Fig. 40.

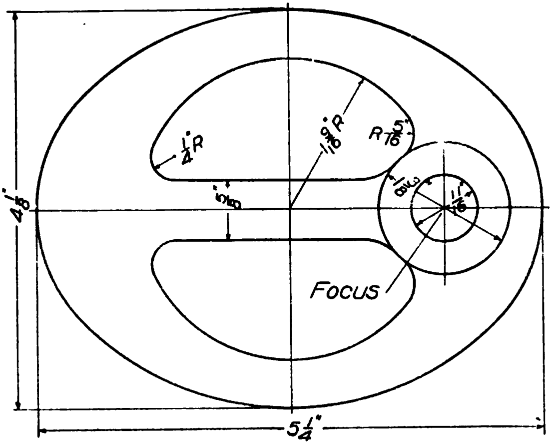


Fig. 40

Exercise 41.—A point on a connecting rod of a stationary engine describes an elliptic curve in one revolution of the crank wheel. With B as the given point lay out the desired curve. The construction for the mechanism may be omitted. Fig. 41.

Exercise 42.—Five-point elliptic arch with three radii. Construction: AB, the altitude, and CD, the span, are given. Lay off the major and semi-minor

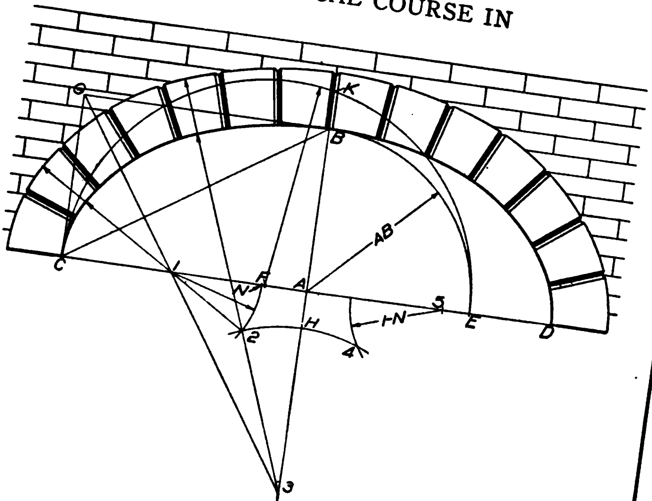


Fig. 41

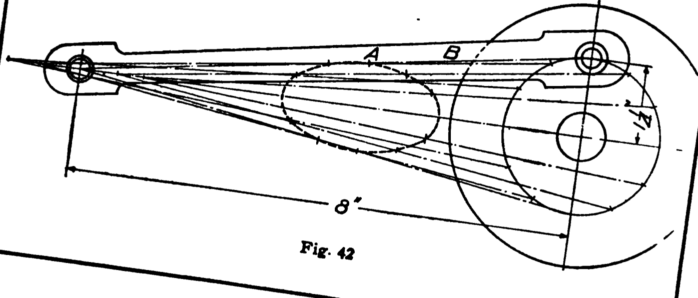


Fig. 42

axes. With A as a center and AB as a radius, draw an arc through BE. Bisect CE at F and describe an arc with CF as radius. CG = AB and is ⊥ to CD. G-3 is ⊥ to BC, and where G-3 intersects CD at 1 is a point of the first center of the ellipse. Where it cuts AB at 3 is another. Make AH=BK. With 3 as a center and 3-H as a radius describe an arc through H. With C as a center and AK as a radius strike an arc at

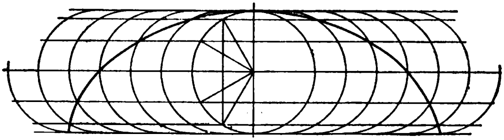


Fig. 43

N. With 1 as a center and 1-N as a radius strike arc at 2, which is another point of a center for the ellipse. With the construction duplicated on the right of the illustration the remaining centers are determined. Points 1, 2, 3, 4 and 5 are the required centers, and all arcs and facing stones radiate from their respective centers. Fig. 42.

Exercise 43.—Cycloid. Fig. 43. A curve generated by the motion of a point on the circumference of a circle which rolls on a straight line is called a cycloid. The figure clearly illustrates the construction. Imagine the rolling circle to be the end of a cylinder.

Exercise 44.—Epicycloid. Fig. 44. An epicycloidal curve is generated by the motion of a point on the circumference of a circle which rolls upon a circle.

Exercise 45.—Hypocycloid. Fig. 45. A hypocycloidal curve is generated by the motion of a point on

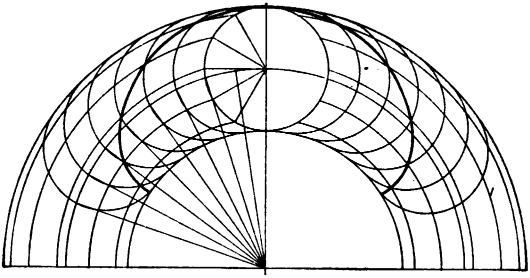


Fig. 44

the circumference of a circle rolling upon the concave side of a circle. Should the diameter of the generating circle = the radius of the larger circle the hypocycloid would become a straight line.

These curves are used in constructing the profile of gear teeth. Fig. 46 is a draftsman's method of laying out the forms of teeth theoretically, the method to the right being involute, and that to the left, cycloidal. Fig. 46*a* is a perspective sketch of the same from a pattern made by a patternmaker in the shop. The size of the rolling circle, 2E, in determining the *epi-* and *hypo*cycloidal curves is not a fixed diameter; however, it is

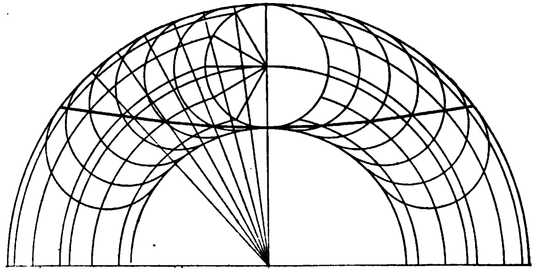


Fig. 45

best to make it one-half the diameter of the pitch circle of the smaller of two engaging gears. In a problem where the diameter of PC, or 2R, and the number of teeth n are given, the circular pitch, which is the dis-

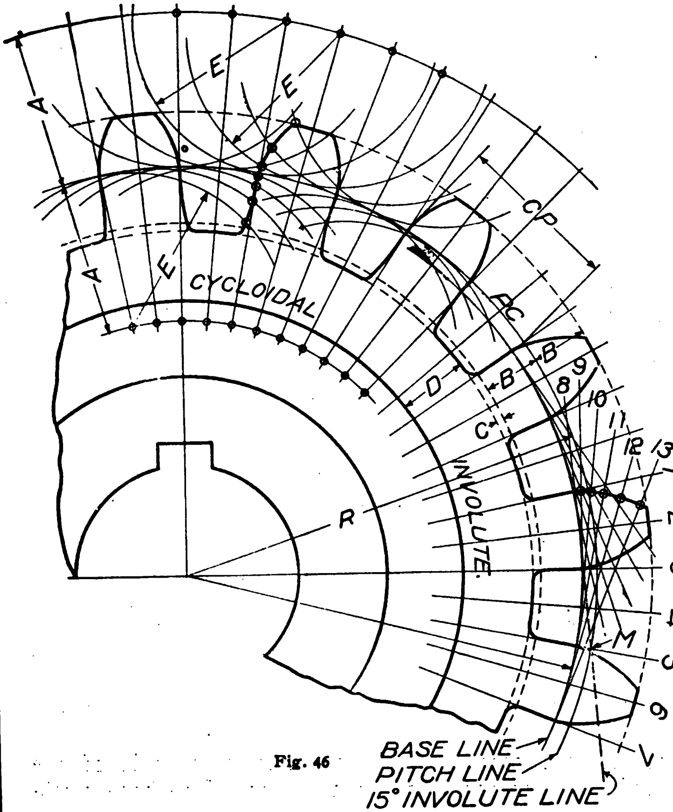


Fig. 46

tance from one tooth to a corresponding point of another, CP, must be laid off first on PC. The involute method is as follows: At the radial line 2 draw a tangent 8 where it intersects the pitch circle PC at 2. Lay off on this tangent the chord of the arc of the PC between radials 1 and 2. This is a point of the curve

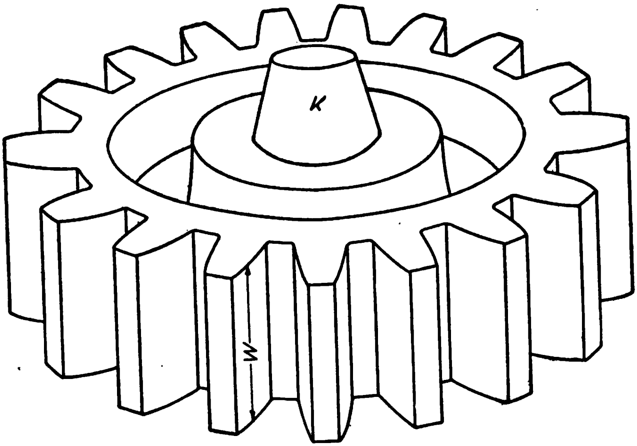


Fig. 46a

of the tooth. Again at radial 3 repeat the above process, but lay off two chords of the arc PC on tangent 9 instead of one; on 10 three chords, and so on until enough points are secured to define the desired involute tooth curve. Reverse the operations for the other side. $\frac{CP}{2}$ = the width of the tooth or space for all purposes *in drafting*. The lower half of the profile of the tooth is a radial line. The base circle

is drawn tangent to the involute line of 15°, through M.

Practically the same principle is involved in laying out the cycloidal tooth except that the chords of arcs on PC are laid off on the arcs of the rolling circle. Above the line PC the rolling circle generates the epicycloidal profile, or *addendum*, while below, the hypocycloidal or *dedendum*. A = E.

The following additional data are given for those who would like to specialize on gear teeth and is arranged from Kent, a well known authority:

$$\left.\begin{array}{l}\text{Addendum} = \text{depth of tooth above PC} = .35\ \text{CP.}\\ \text{Dedendum} = \text{depth of tooth below PC} = .35\ \text{CP.}\end{array}\right\}\ \text{B}$$

Clearance at root of space = .05 to .1 of CP. (C.)

$$\left.\begin{array}{l}\textit{Actual}\ \text{thickness of tooth on PC} = .45\ \text{of CP.}\\ \textit{Actual}\ \text{width of space on PC} \doteq .55\ \text{of CP.}\end{array}\right\}\ *$$

Backlash, or play between engaging teeth = .1 of CP.

Circular pitch = a tooth and space on PC and is more commonly used than diametral pitch.

Diametral pitch = a certain number of teeth per inch of diameter of PC.

If DP = 1 CP = 3.1416.
= 1½ = 2.094.
= 2 = 1.571.
= 2¼ = 1.396.
= 2½ = 1.257.

From the above it is seen that a π (pi) relation exists between circular and diametral pitch, i. e., if π be divided by DP the result will be CP; or if π be divided by CP the result will be DP.

*Are about equal in machine cut gears.

Let $n =$ number of teeth.

$$CP = \frac{\pi D}{n} \text{ when } D = \text{diameter of PC.}$$

$$n = \frac{\pi D}{CP}$$

The thickness of rim D = .12 + .4 CP.

The width of face, W, Fig. 46*a*, averages 2 to 2½ CP.

The diameter of hub = twice the diameter of shaft.

Thickness of web connecting hub and rim varies.

Arms are used on larger gears. Holes are often drilled through the web to lighten the weight without destroying the efficiency of the gear wheel. The length of the hub may be flush with the rim, but is usually ¼ inch or more longer.

The "face" of a tooth is the distance B above PC. The "flank" of a tooth is the distance B below PC. "K," Fig. 46*a*, shows the position of the core print used in molding the hole for the shaft.

Problem 1.—Draw the front and side views of a gear wheel having 24 teeth, 2¼ diametral pitch, with epicycloidal profile of teeth. Scale, full size.

Problem 2.—A pinion for a certain gear has 27 teeth. CP is 1.571 inch. Draw forms of teeth by involute method. Scale, half size.

Note: A pinion is the smaller of two gears acting together and should not have less than 12 teeth.

Problem 3.—A recent examination for a city high-school position contained the following question:

Make a scale shop drawing of a pair of meshing

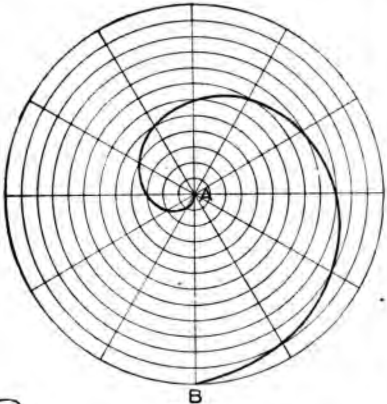


Fig. 47

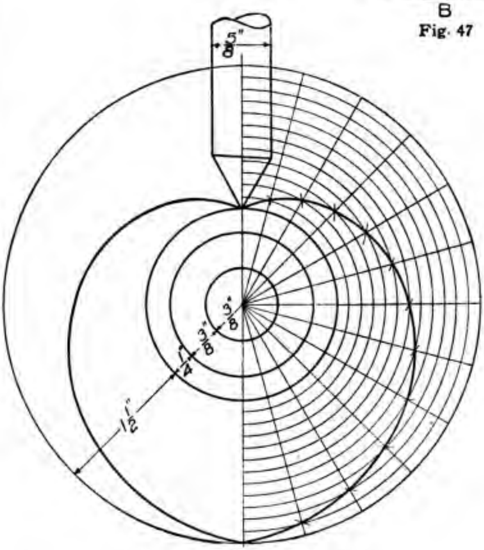


Fig. 48

gears of 8 diametral pitch. One gear to be a plain gear, to have 32 teeth, 1-inch face, 1-inch bore, one hub 7/8 inch long and to be the *driver*. The *following* gear to be a web gear and to travel at two-thirds as many r. p. m. (revolutions per minute) as the driver. The follower to have a 5/16-inch web, 1/4-inch rim or backing and 2-inch hubs, one hub being flush and the other 7/8-inch long. Each gear to be held on the shaft by two kinds of fastenings. All dimensions and details, not here specified, to be assumed at the option of the draftsman to make the mechanism of ordinary and reasonable proportions. Driver and follower to be designated. Driver to be finished all over (f. a. o.); follower to be finished (f.) at rim, also on ends and outside of hubs.

Note: Profile of teeth not necessary for cut gears. Scale, full or double size.

Exercise 46.—Archimedean spiral of one whorl. Construction: With a radius equal to the rise of the spiral AB, and A as a center, describe a circle. Divide AB into as many equal divisions as the circle has been divided into sectors. Lay off successive arcs on the radials and draw in the curve. If a spiral of 2 whorls is desired divide AB into twice as many parts as for one whorl. This problem represents a cross section of the Nautilus, a sea shell described by Oliver Wendell Holmes in "The Chambered Nautilus." Fig. 47.

Exercise 47.—Heart plate cam. Fig. 48. The construction for this common object may be derived from Exercise 46 and the figure. The sewing-machine bobbin-winder is one of several applications of its use.

Exercise 48.—The involute spiral. This curve is developed by unwinding a string wrapped about a

cylinder, the end describing the involute. Construction: Lay off tangents at regular intervals to the cylinder. On the first tangent line step off the chord of one arc. On the second tangent, two chords; on

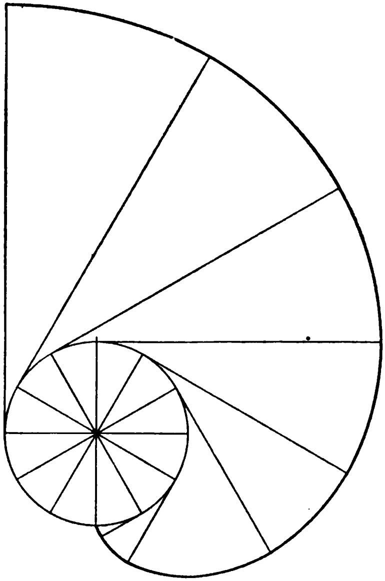


Fig. 49

the third, three, etc. Draw the curve through the points. Fig. 49.

The involute is used in defining the tooth curve of a gear wheel.

Exercise 49.—Helix. Fig. 50. A definition of a helix may be given as the combined vertical and hori-

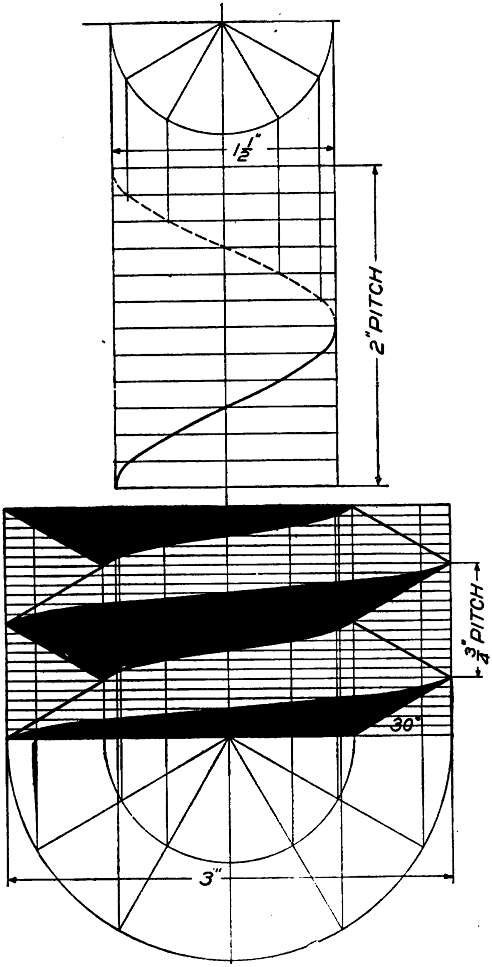


Fig. 50

zontal motion of a point about a right line as an axis, no two points of the curve lying in the same plane. The upper part of Fig. 50 shows this part laid out apart from its application to the screw thread. Construction: Lay out the plan and elevation of the thread desired.

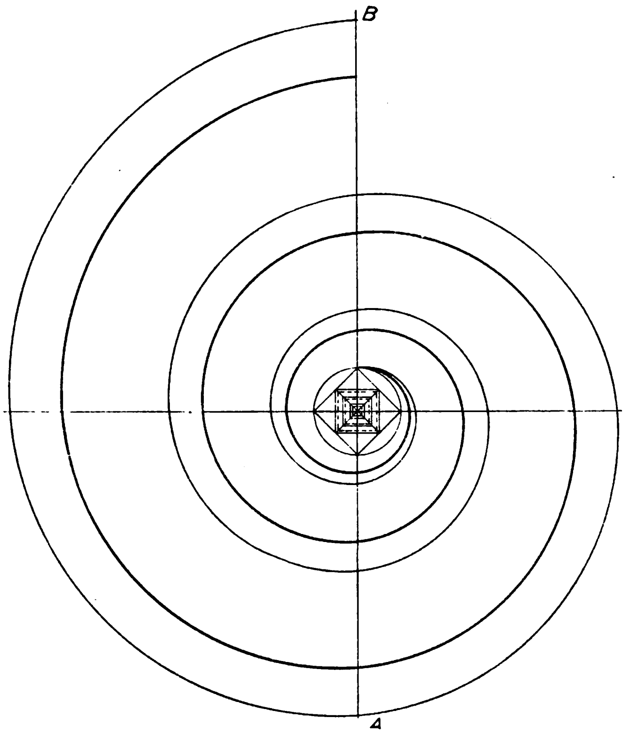


Fig. 51

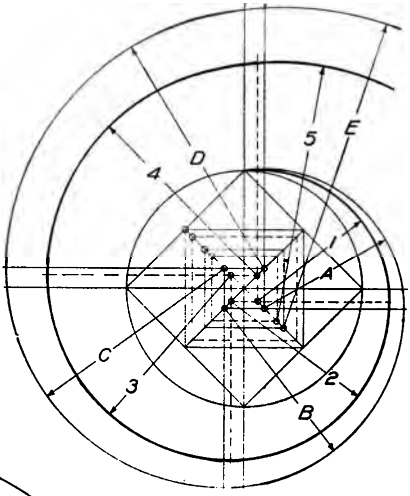


Fig. 52

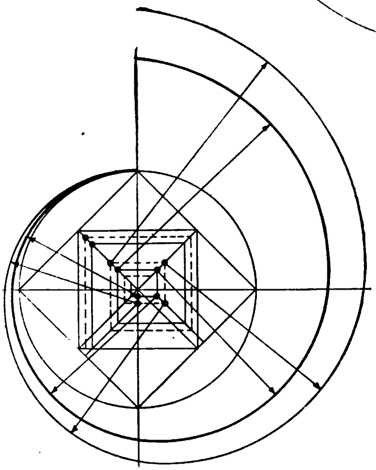


Fig. 53

Divide the half section of the plan into any number of equal parts and divide the pitch into as many. The curves are obvious from the illustration, which is a *single* thread. By a single thread is meant the winding of one screw thread about the bolt-cylinder. A double requires two threads parallel to each other; a triple, three, and a quadruple, four. Fig. 55 represents a conventional method of showing the single thread in practice. No attention is paid to the theoretical helical curve in drafting; however, it is essential to have a proper understanding of it.

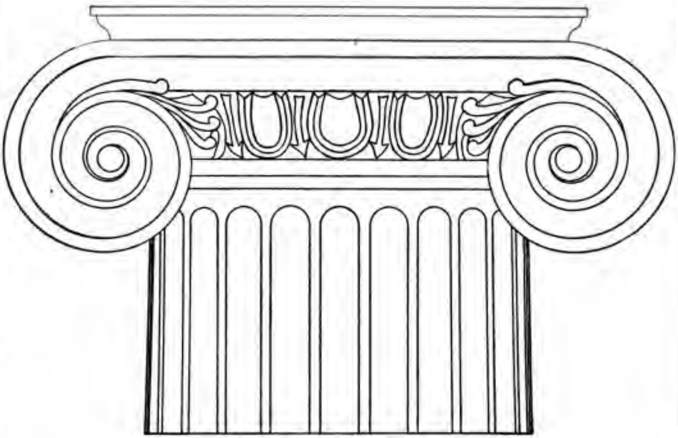


Fig. 54

Exercise 50.—Ionic volute. Figs. 51, 52, 53 and 54. Fig. 51 is an illustration of the volute spiral of an Ionic capital in classic architecture (Fig. 54). In laying

out such a curve, either method, Fig. 52 or Fig. 53, may be used with the same results. When AB is given (Fig. 51), make the eye of the volute 1/16 of AB and locate its center on the ninth division of AB. Divide

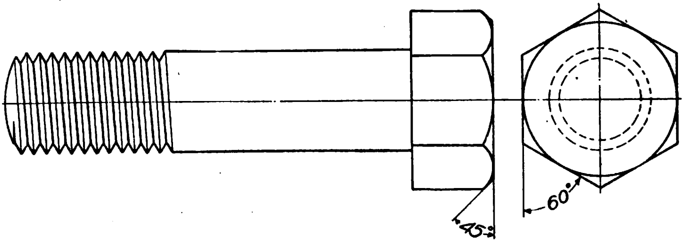


Fig. 55

the semi-diagonal of the square into three equal parts and construct squares through these points, as in Fig. 52. Each corner of these squares is a center for *quadrants* of the outer spiral starting with radius A. The inner dotted squares are drawn to pair within the first squares, a distance of one-third the space between the first series of squares. Proceed with the construction of the spiral following consecutive radii.

The second method is practically the same as the first, just described. The radii of the first quadrants, both inner and outer, are taken on the line CD. Follow the unbroken lines until the spiral is completed. The construction of the diagonal in beginning this method is the same as in Fig. 52. The *offset* diagonal is equal to one of the smaller spaces on the diagonal.

Exercise 51.—Draw a 1-inch bolt of 3 inches length. There are 8 threads per inch. The angle of the V's in the U. S. Standard or Sellers thread is 60°. Note the difference between a single and double V thread in

the conventional layout. A square has half as many threads as a V of the same diameter. Show length of bolt from underneath edge of head to the end of the cylinder. Figs. 55 and 88.

Ornamental and decorative art implies the use of geometry in laying out designs and patterns in stained or art glass, carpets, wall-paper, oil-cloth, borders, ornamental iron, woodwork and carving, carpentry and cabinetmaking, pottery, china painting, floor-tiling, and in bookbinding. Meyer, in his "Handbook of Ornament," says: "In medieval times these geometric constructions developed into practical artistic forms as we now see them in Moorish paneled ceilings and Gothic tracery." In the exhibit of Indian relics in the Field Museum one may also see traces of geometric design in the tattoo and decoration of the implements of the savage. The history of some of these designs is very interesting, particularly the Swastika and the Maltese cross.

Geometric motives may be obtained from the flowers. The trilium, daisy, columbine and lilac are illustrations of the triangle, circle and polygon. These may be arranged into rosettes, borders and stencils, using a circle as a unit.

The illustration of the trefoil, Fig. 32, is a design of a monogram of an appropriate initial.

Problems pertaining to decorative design will not be given in this course, but will be reserved for a later work.

CHAPTER IV

WORKING DRAWINGS

ELSEWHERE reference has been made to the value and importance of a working drawing in the shops. No reliable workman should attempt a new problem without a working drawing having previously

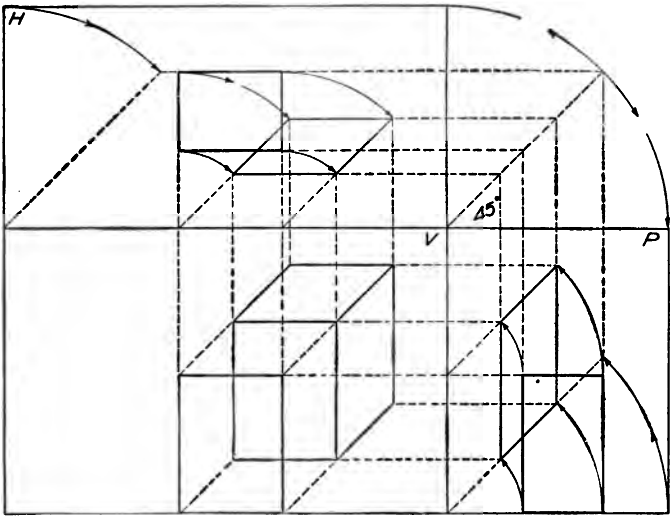


Fig. 56

been made. No first-class foreman should permit any other kind of a workman to begin a responsible task without having ample directions in plan and elevation.

By a "plan" is meant the appearance of the top of an object when observed from above. By "elevation"

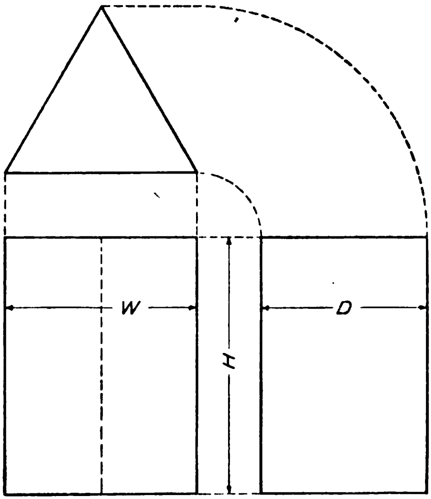


Fig. 57

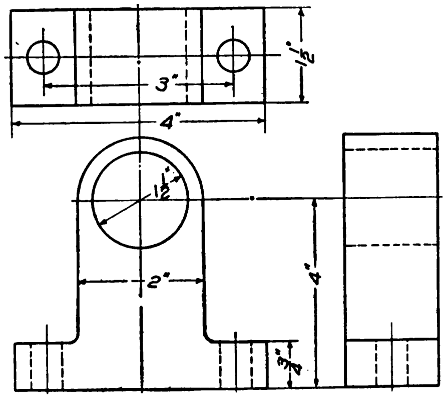


Fig. 58

is meant the appearance of the object when observed from the front or side. Having three views of the object, any ordinary problem in the shops may be made clear. Occasionally a very irregular object requires special views, but for our immediate purpose these will be omitted.

Suppose a model be placed within a glass case and a plan view traced on the upper surface. Likewise trace a view of the front and side. Now open each plane until top, front and side lie in one flat surface as in Fig. 56. This is the working drawing, or three projected views. Both H and P planes revolve through 90°. Note the references to height (H), width (W), and depth (D), together with the method of obtaining them from one view and carrying to another, in Fig. 57.

If a glass case with hinged sides is not conveniently acquired select and invert a good pasteboard shoe-box over any geometric model. Sever all but the front edges, which are to serve as hinges. Outline on the surfaces the shape of the several views and then cut out the outline from the H, V and P planes. A chalk-box, pencil-box, prism, or any object which is simple in shape, will serve well as a drawing exercise. Many problems should be drawn to firmly fix the fundamental principles of projection which underly the working drawing. While the geometric exercises form the basis of all mechanical drawing, the details and principles of the workman's drawing are the most used and practical application of constructive drawing.

The craftsman, patternmaker, machinist or carpenter must each have a definite plan or idea prescribed before him in the form of a blueprint working drawing. The first thought of any constructive character must

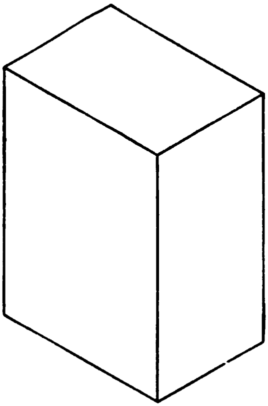


Fig 59.

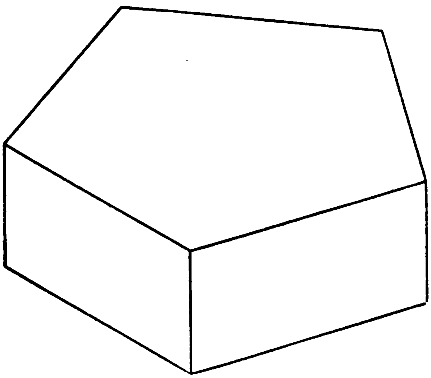


Fig. 60

always first appear on paper, and the common means of that representation is the above-described kind of drawing. Fig. 58.

PROBLEMS

1. Draw three views of the rectangular prism. Fig. 59.

2. Draw three views of the pentagonal plinth. Fig. 60.

3. Draw two views of the bushing pattern. Fig. 61.

4. Fig. 62 is a representation of an angle iron. Draw three views and dimensions.

5. Fig. 63 is a drawing of a cast-iron block. Two views and dimensions.

6. Fig. 64, pillow-block bearing. Three views and dimensions.

7. Fig. 65, tool post holder. Three views and dimensions. Scale half size.

8. Fig. 66, rocker. Three views and dimensions.

9. Fig. 67, crank arm. Two views and dimensions.

10. Fig. 68, core box for pipe tee. Three views and dimensions.

11. Fig. 69, coupling. Two views and dimensions.

12. Fig. 70, V block. Three views and dimensions.

13. Fig. 71, drawing of a pattern for a shaft bearing without the cap. Draw three views.

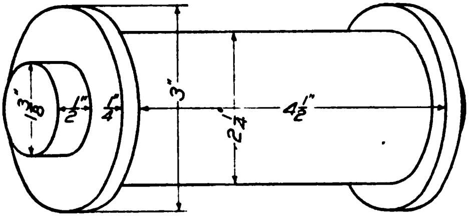

3"
$4\frac{1}{2}$"
$2\frac{1}{4}$"
$\frac{1}{2}$"
$\frac{1}{4}$"

Fig 61

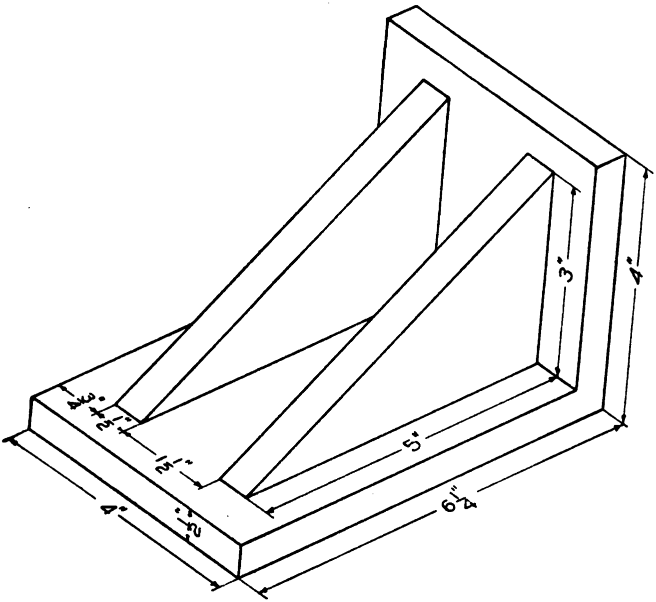

3"
4"
5"
$6\frac{1}{4}$"
4"
$1\frac{1}{2}$"
$\frac{1}{2}$"
$\frac{3}{4}$"

Fig. 62

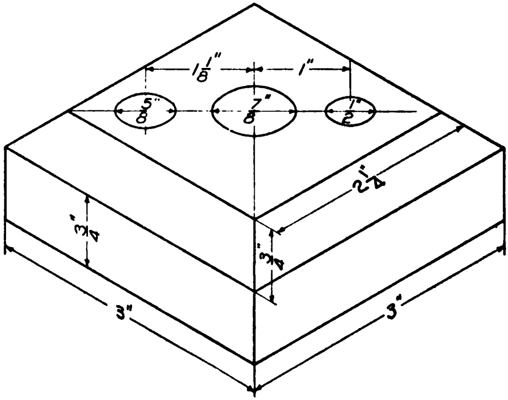


Fig. 63

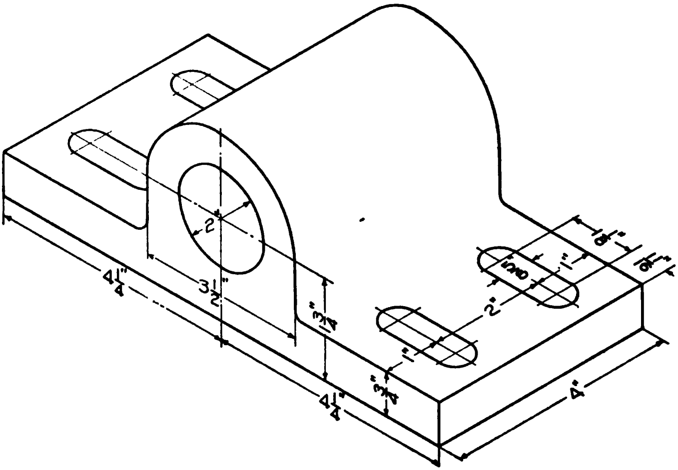


Fig. 64

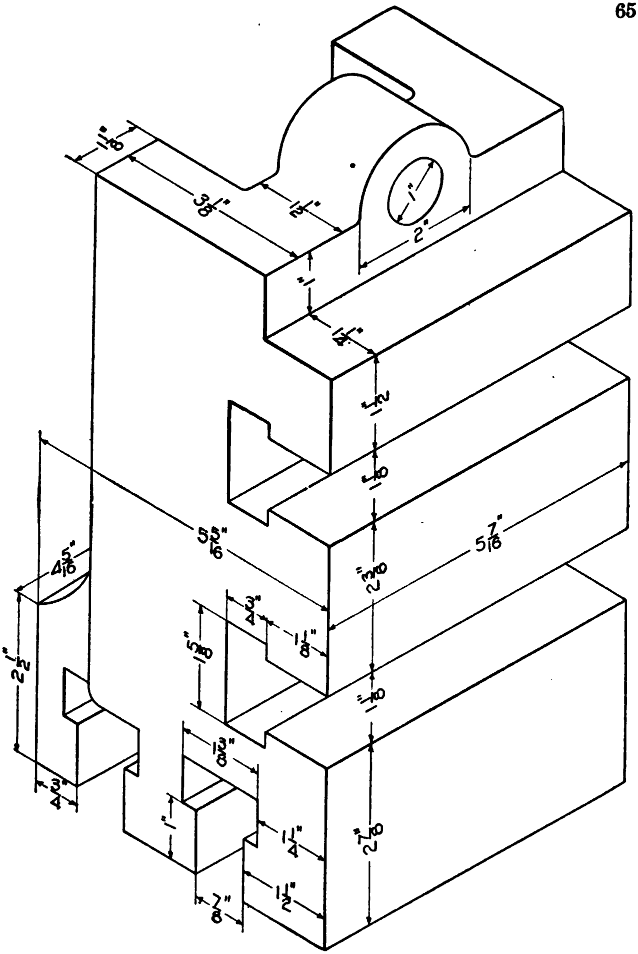

1 1/8"
3 1/8"
1 1/2"
1"
2"
1"
1 1/4"
1 1/2"
1 1/16"
5 5/16"
5 7/16"
2 3/16"
4 5/16"
3/4"
1 1/8"
1 5/16"
1 1/16"
2 1/2"
1 3/8"
1"
1 1/4"
3/4"
7/8"
1 1/2"
2 7/16"

Fig. 65

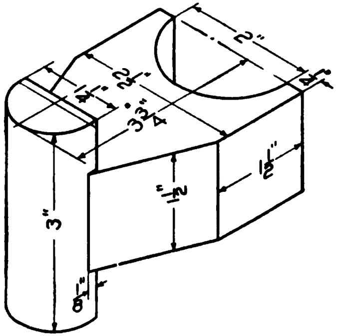


Fig. 66

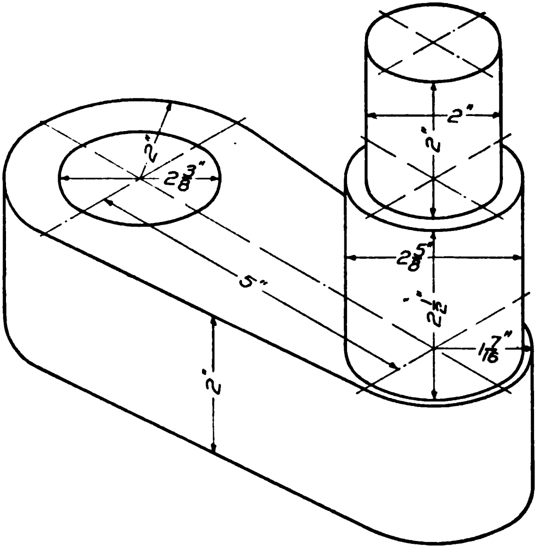


Fig .67

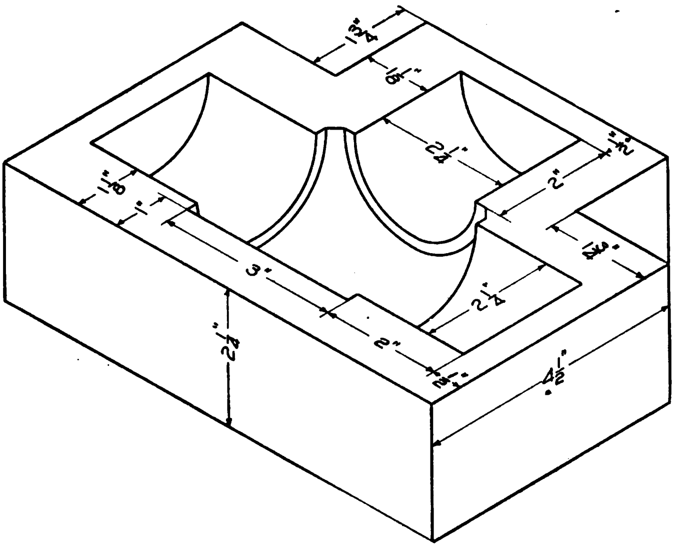


Fig. 68

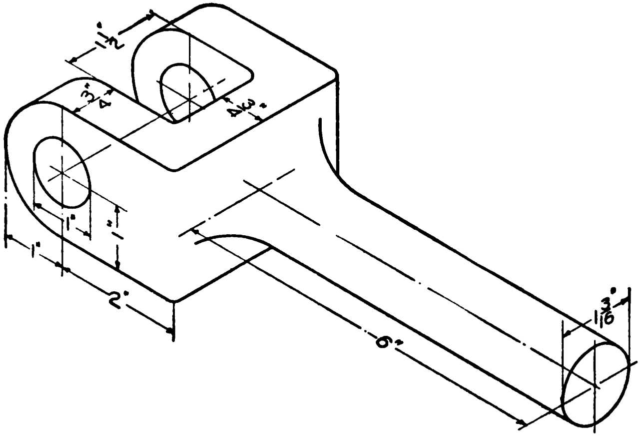

1½"
¾"
¾"
1"
1"
1"
2"
6"
1 3/16"

Fig. 69

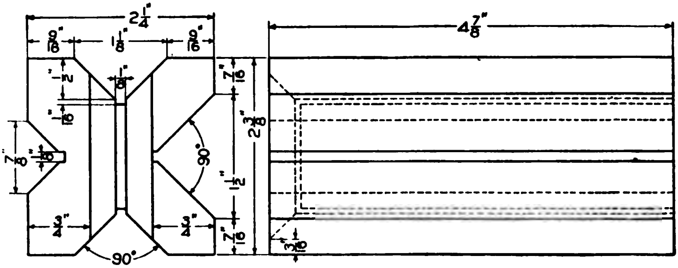

2¼"
9/16"
1⅛"
9/16"
4⅞"
½"
⅛"
1/16"
7/8"
1/8"
90°
90°
¾"
¾"
7/16"
2⅜"
1½"
7/16"
3/16"

Fig. 70

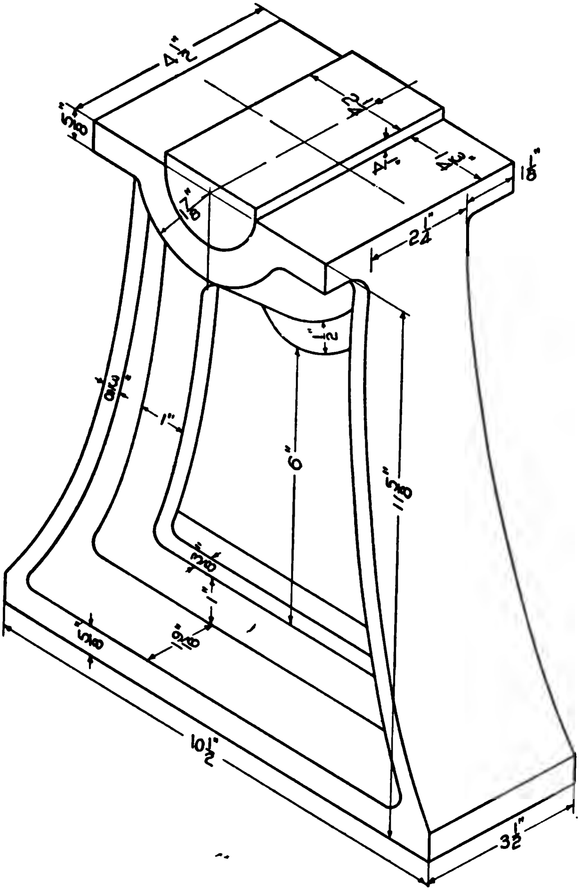

$4\frac{1}{2}''$
$\frac{5}{8}''$
$2\frac{1}{4}''$
$\frac{1}{4}''$
$1\frac{3}{4}''$
$\frac{1}{8}''$
$1\frac{7}{8}''$
$2\frac{1}{4}''$
$\frac{1}{2}''$
$\frac{3}{8}''$
$1''$
$6''$
$11\frac{5}{8}''$
$\frac{3}{16}''$
$1''$
$\frac{5}{16}''$
$1\frac{9}{16}''$
$10\frac{1}{2}''$
$3\frac{1}{2}''$

Fig. 71

CHAPTER V

CONVENTIONS USED IN DRAFTING

CONVENTIONS, as explained in a previous chapter are customary methods or symbols established by usage and precedent and are generally employed for the sake of uniformity and convenience the world over. Their use and convenience will be readily understood by the student.

a. Circles require two center lines, and must always be shown.

b. Invisible edges are shown by a series of 1/8-inch dashes with 1/16-inch space.

c. Visible edge lines take precedence over invisible lines when they coincide.

d. Dimension lines are very light, continuous, and broken only for dimensions, near the center.

e. Dimensions should read at right angles to the dimension lines in the working drawing.

f. Sharp, snappy arrow-heads should attach to the ends of each dimension line.

g. The summation, or aggregate of several dimensions tending in any one direction, should be shown separately, that the workman may not err in calculating the over-all sizes of stock required for the finished product.

h. Projection lines are light single dashes of any desirable length extending from view to view to facilitate the placing of the dimensions. They should not touch the projections of the figure.

i. Space too small for dimensions should have ar-

rows outside and directing toward the space to be dimensioned.

j. The draftsman's figures are to be used for all numerals, or fractions, which must be common shop units, as $\frac{1}{32}$, $\frac{3}{16}$, $\frac{5}{8}$, $\frac{3}{4}$, etc., and not $\frac{1}{3}$, $\frac{1}{6}$, $\frac{1}{10}$, $\frac{1}{12}$. The bar which separates the numerator from the denominator should always be horizontal to avoid any possible mistake in reading a dimension.

k. Section planes have the same convention as center lines.

l. All edges of material which are shown cut by a plane in the drawing, are solid lines.

m. Adjacent pieces in an assembly of parts must be crosshatched at right angles, or in different directions. Do not space too closely.

n. Dimensions are not so likely to be overlooked by the workman if placed to the right and between the views as much as possible.

o. Do not permit dimension lines to cross each other.

p. Show dimensions between center lines and "finished" surfaces. They are most important in any drawing.

q. Sections are shown to make clear hidden details of construction. They should be frequent and properly located in complex drawings.

r. Do not repeat dimensions except in a very complicated drawing.

s. Always place full-size dimensions on the drawing, no matter what scale is used.

t. Locate the "front" elevation first.

u. Invisible parts behind sections are never shown.

v. Bolts, shafts and screws are never sectioned. A broken cross-section of a bolt or shaft should show the convention of material.

w. Show diameters in preference to radii.

x. Never cross-hatch over dimensions.

y. Arcs of circles and curves should be drawn before straight lines which adjoin them.

LETTERING

One of the most important features of any drawing, and one most neglected on the part of a student or amateur draftsman, is the neat appearance of every detail. These details consist chiefly of letters, figures, notes, titles, scales, stock lists and bills of materials—data which, if executed neatly and with precision, increase the appearance a hundred-fold of what might otherwise be a poor drawing.

Architectural and mechanical draftsmen are obliged to letter well to retain their positions in many concerns although they may be expert in draftsmanship. Competitive and Patent Office drawings must, of necessity, look neat in every particular in order to receive a consideration of merit. This is why technical schools insist, with emphasis, upon this additional good quality of their student's work.

Notebooks, examination papers, programs and themes appear much better when their titles are well lettered than when scribbled in some unreadable characters.

NOTE TO THE TEACHER: A better impression of a student is derived from the manner in which he presents his work, than from how much work he presents. Insist that what he does be done well, and what he lacks in quantity will be more than made up in quality.

If cross-sectioned paper is not available, it will be

THE FOLLOWING IS A GOOD EXERCISE AND CONTAINS ALL THE LETTERS OF THE ALPHABET:–

"THE QUICK BROWN FOX JUMPS OVER THE LAZY DOG."

HARD PRACTICE IS A GOOD MASTER.

THE DRAFTSMAN'S FIGURES ARE ALWAYS USED. 1 2 3 4 5 6 7 8 9 0 $\frac{1}{2}$" $\frac{13}{16}$"

ALL LETTERS AND FIGURES SLOPE HALF THEIR HEIGHT, OR ABOUT 30°.

Fig. 72

This lower case style is a very popular form of letters for notes, titles, stock-lists, bills of material, etc.

"A quick brown fox jumps over the lazy dog."

Stem letters are $\frac{3}{16}$ths of an inch high. Use a ball-pointed pen #506 or #516.

ABCDEFGHIJKLMN
OPQRSTUVWXYZ 30°

Fig. 73

well to "rule" a sheet into $\frac{1}{8}$-inch squares and draw "slope" lines about 30° from a vertical, as in Fig. 73. Pencil all letters freehand for guides, with a 2H pencil, and submit for approval. (Note: Do not mistake a No. 2 pencil for a 2H. Any good stationer will explain the grading of pencils.) Ink with Higgins' India ink and ball-pointed pen, No. 506, or 516.

Fig. 72 is an exercise which contains all the letters of the alphabet. Some such sentence as this is usually

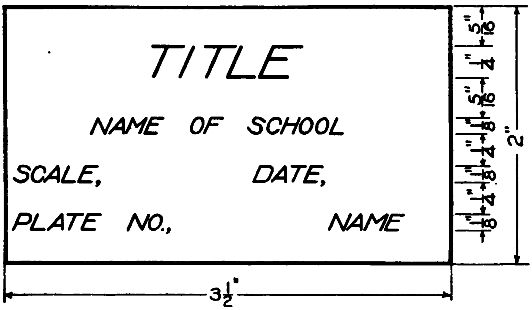


Fig. 74

given in commercial schools to develop skill on the typewriter. Lower-case or small letters are shown in Fig 73. "Lower-case" is a printers' term, printers' type cases being so arranged that the capital letters are contained in the upper and the small letters in the lower compartments. In Fig. 74, a title is shown. Note that the most important part of the title is the object of the drawing and hence should be more prominent than the rest. A title should be so balanced that one side will not appear to "see-saw" or be heavier than the other. All drawings should be titled prop-

THIS FREEHAND GOTHIC STYLE OF LETTERS SHOULD BE USED ON ALL DRAWINGS NOT ARCHITECTURAL OR TOPOGRAPHICAL.

MAKE ALL LETTERS UNIFORMLY HIGH, $\frac{1}{8}$TH INCH IF LOWER CASE AND $\frac{1}{4}$TH IF CAPS. THIS STYLE IS $\frac{1}{8}$TH CAPS.

DRAW LIGHT GUIDE LINES FOR THE SLOPE AND HEIGHT. WIDE LETTERS ARE BEST. SPACE BETWEEN WORDS SHOULD NOT BE LESS THAN $\frac{1}{4}$TH INCH, NOR MORE THAN $\frac{3}{8}$THS. KEEP LETTERS IN EACH WORD COMPACT.

GOOD LETTERING ENHANCES THE APPEARANCE OF ANY DRAWING.

NEATNESS AND LEGIBILITY ARE VALUABLE ASSETS IN MECHANICAL DRAWING.

DO NOT USE A VERTICAL STYLE.

Fig. 75

erly. The titles need not be circumscribed by a 2x3½-inch boundary, but the proportion of the spacing between lines and heights should remain as in the illustration. Place the title plate in the lower right-hand corner, about ½ inch from the margin line.

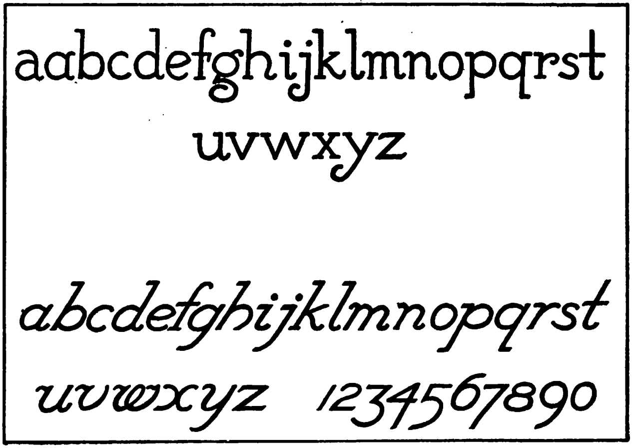


Fig. 76

Oval letters and figures are constructed on the form of the letter "O." Make the letter "O" and then modify to suit the shape of the desired letter or figure.

Draw all downward strokes first, then curves or intervening lines as indicated in Fig. 73.

Practice lettering the exercise given in Fig. 75 until proficiency is assured.

Fig. 76 is an architectural style of letter.

CHAPTER VI

MODIFIED POSITIONS OF THE OBJECT

SUPPOSE the prism in Fig. 59 (Page 61) be revolved about a vertical axis, *i. e.,* an axis ⊥ (perpendicular) to the H plane. Looking down on the prism in Fig. 59, how would the plan be drawn if the

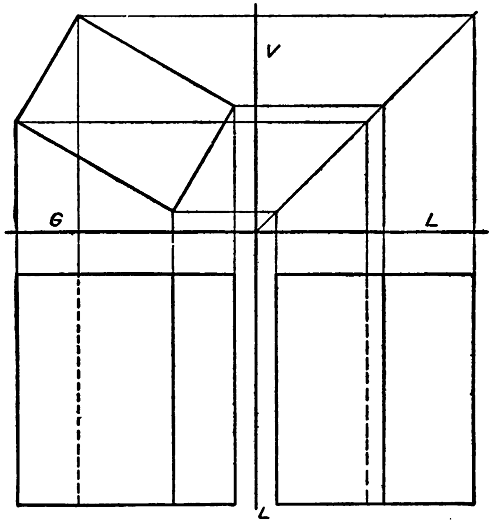


Fig. 77

object be revolved 30° about a vertical axis? Does the altitude and the construction of the plan view alter in such a revolution? Use the chalk-box as a model until each step in the thinking process is clear. Now draw the remaining views. Through how many de-

grees does the earth revolve? May anything revolve? Any point of the object always moves in a plane ⊥ to the axis. There are 360 degrees in a circle.

Principle 1.—When an object revolves about a vertical axis (⊥ to H) its plan view is not altered in shape,

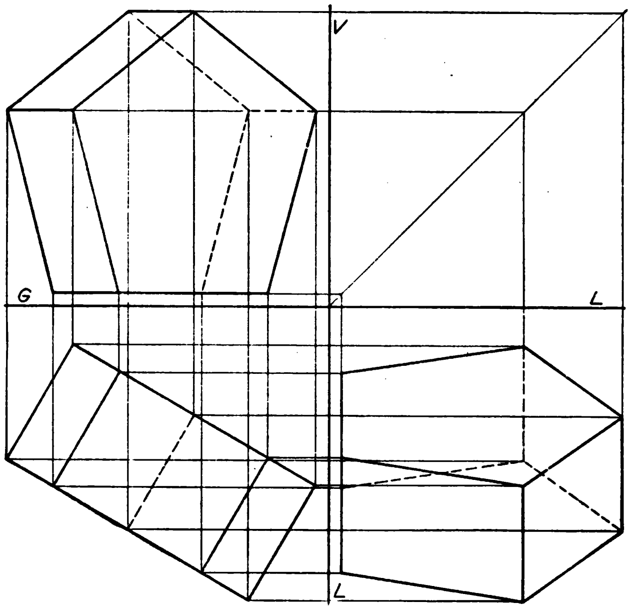


Fig. 78

but only in position, and the height remains the same. Fig. 77.

Note: No distinction is here made between "vertical" and "perpendicular," as the H plane is always considered horizontal.

Find the projections of the plinth in Fig. 60 (p. 61) when it is revolved through an angle of 30° about a side axis, i. e., // (parallel) to the profile or side plane. The observer will note here that each point of the object revolves in a circular plane, or path, through 30°, about the side axis, which can only be seen as a point from the front. Therefore, the front elevation will not be altered in construction from its original and natural position, but its position will be 30° inclined to the base upon which it originally lay. Find its remaining projections. Looking down on the plinth in Fig. 60, as on the prism, when it is revolved about a side axis (⊥ to V) we discover that the depth or thickness does not alter, but the construction of the plan changes.

Principle 2.—When the object revolves about a side axis (⊥ to V) to the right or left, its front elevation does not change, save its position, and the depth (D) remains the same. Fig. 78.

Find the three views of the frustum of the pyramid, Fig. 79, when it is revolved through an angle of 30°, forward or backward, about a front axis (⊥ to P).

In this instance we must first observe the position of the object from the profile or right-side plane. The revolution about the front axis, which may be seen as a line parallel to the ground line, GL, and passing through the center of the model, is then accomplished by tilting the side elevation forward or backward, the lower edge making the required angle with the base upon which the object stands. Looking down on the prism in Fig. 59, again, it will be seen that the width of the object does not alter when it is revolved forward or backward. Draw the three projections when so revolved, commencing with the side, then the

front, and the plan last. In this case all points of the object revolve in planes, which the observer can only see as straight lines // to VL.

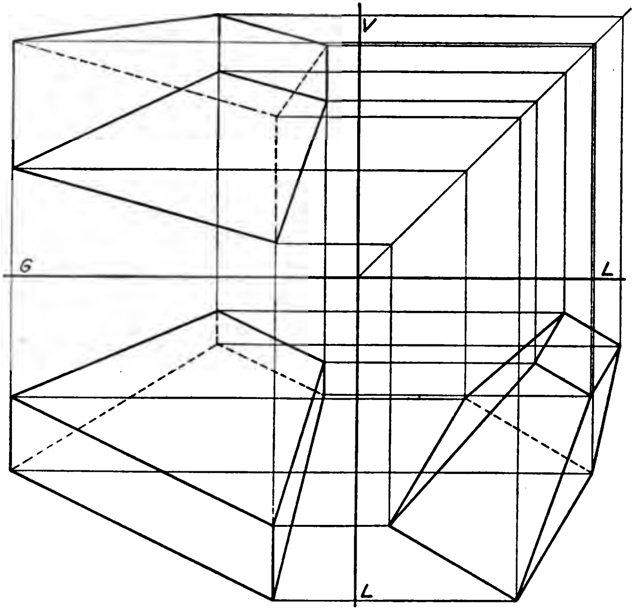


Fig. 79

Principle 3.—When the object revolves about a front axis (⊥ to P), forward or backward, its side elevation does not change save in its position, and the width remains the same.

CHAPTER VII

THE DETAILED WORKING DRAWING

A MACHINE is a composition of many parts. Each part performs a certain function and bears a close relation to adjacent members. If a mechanic desires to make a machine, he must organize the parts perfectly so that a minimum amount of friction is had to do the required work. When each part is made in the shops every specific detail is worked out separately. In the problem of the connecting rod, every detail is illustrated in such a manner that it will be very easy to imagine the size, shape, and to some degree, at least, the relative position of the parts when assembled together. The connecting rod carries the power direct from the cylinder through the piston to the drivers of a locomotive. This object is a detail of a stationary engine. A detailed working drawing is made to enable the mechanic to construct each detail without confusion.

From the illustrations make a working drawing of each separate part, and then fit them together in an assembly drawing.

Figs. 80 and 81 are parts of a bearing which surround the cross-head pin and fit in the left-hand end of the rod, Fig. 87. Fig. 82 is a tapered key-block used to take up wear and is located behind Fig. 80. Figs. 83 and 84 are parts of the bearing which fit around the crank-pin and are located on the right end of the rod, Fig. 87. A strap, Fig. 85, holds these two parts together with another tapered key-block, Fig. 86, by means of half-inch bolts. Two ½-in. bolts, 6 in. long, Fig. 88, fasten the strap to the rod. Each tapered key-

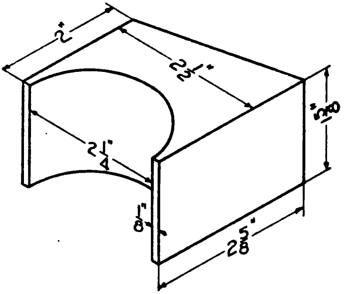


Fig. 80

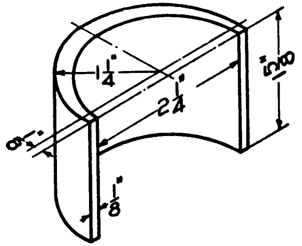


Fig. 81

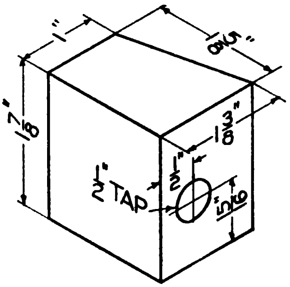


Fig. 82

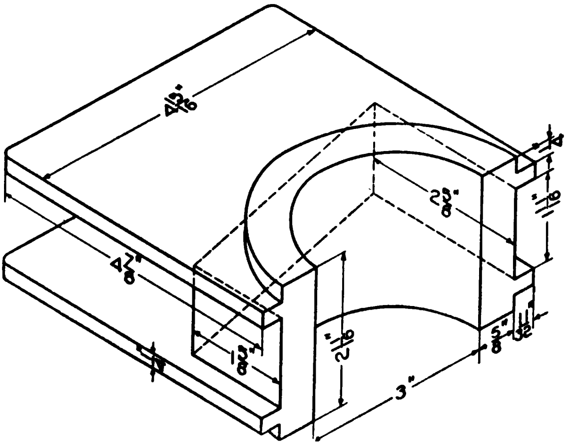


Fig. 83

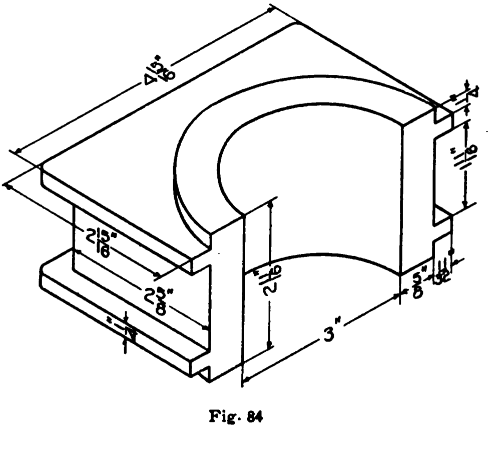
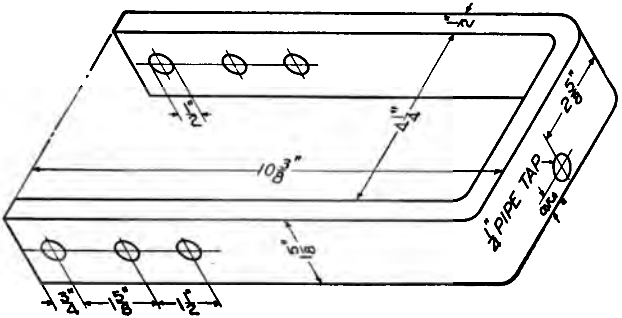
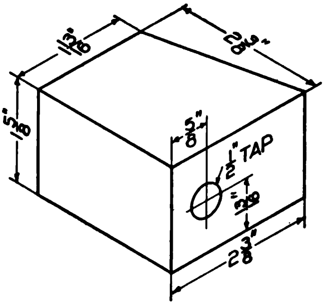


Fig. 84



$\frac{1}{2}$"
$\frac{1}{2}$"
$4\frac{1}{4}$"
$10\frac{3}{8}$"
$2\frac{5}{8}$"
$\frac{1}{4}$" PIPE TAP
$\frac{5}{16}$"
$\frac{3}{4}$"
$1\frac{5}{8}$"
$1\frac{1}{2}$"

Fig. 85



$1\frac{3}{16}$"
$2\frac{3}{8}$"
$1\frac{5}{16}$"
$\frac{5}{8}$"
$\frac{1}{2}$" TAP
$2\frac{3}{8}$"

Fig. 86

block has two ½-inch bolts, one on each side of the strap. This makes six bolts in all. The hole on the end of the strap is for oil. Copy in Gothic slant letters the stock list. Fig. 89.

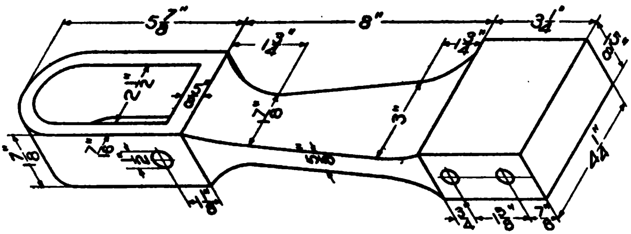


Fig. 87

When the drawing of a machine problem is completed, it is first sent to the patternmaker, who makes a model in wood from it. He must know from experience the amount of material to allow for shrinkage

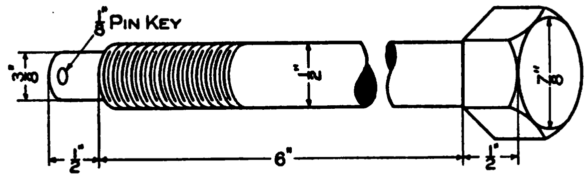


Fig. 88

of the casting in cooling, how much to allow for polishing or "finishing," and how much taper for "draft" in withdrawing the pattern from the mold. The pattern is then sent to the foundry, where it is molded in sand. After the form has been made it is "poured," that is,

filled with melted ore from the cupola. When the casting is cool enough to handle, it is sent to the machine-shop to be machined and "dressed" ready for use.

Here, again, the working drawing must be brought

STOCK LIST

MARK	NO. WANT	NAME	MATERIAL	REMARKS.
80-81	1	BEARING	PH. BRONZE	2 PARTS
82	1	KEY-BLOCK	STEEL	F.A.O.
86	1	" "	"	"
83-84	1	BEARING	PH. BRONZE	FINISH BABBITT
85	1	STRAP	STEEL	F.A.O.
87	1	ROD	"	"
88	2	BOLTS	W.I.	$6'' \times \frac{1}{2}''$ D
	1	"	"	$3'' \times \frac{1}{2}''$ D
	2	"	"	$1\frac{3}{4}'' \times \frac{1}{2}''$ D
	1	"	"	$1\frac{1}{2}'' \times \frac{1}{2}''$ D

Fig. 89

into use, for the machinist is obliged to follow the specifications thereon, regardless of what he might think ought to be done in the case. This places all the responsibility of error upon the draftsman.

A detailed working drawing, as applied to the wood-working and building trades, is also a very important application of the working drawing. It is fully as

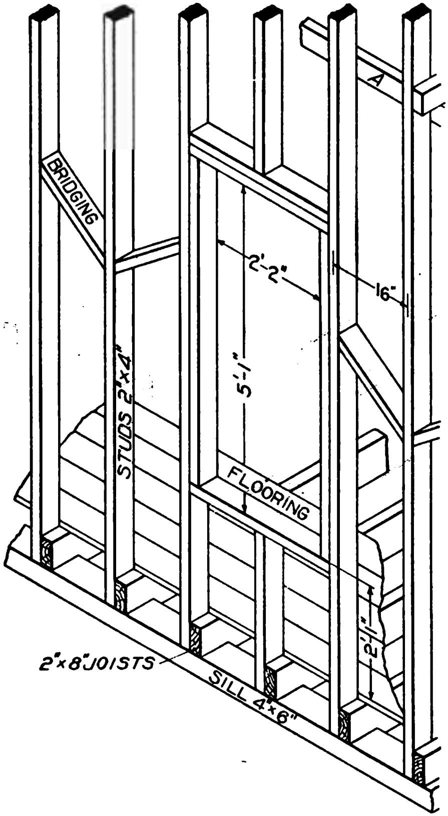


Fig. 90

necessary that such a drawing be as carefully made for the carpenter or cabinetmaker as for the machinist or engineer, and no skilled workman should attempt a task requiring skill and accuracy without it.

For erecting the framework of a cottage, details specific and clear must accompany the plans and elevations. Studs, sills, rafters, sashes, joists, etc., should

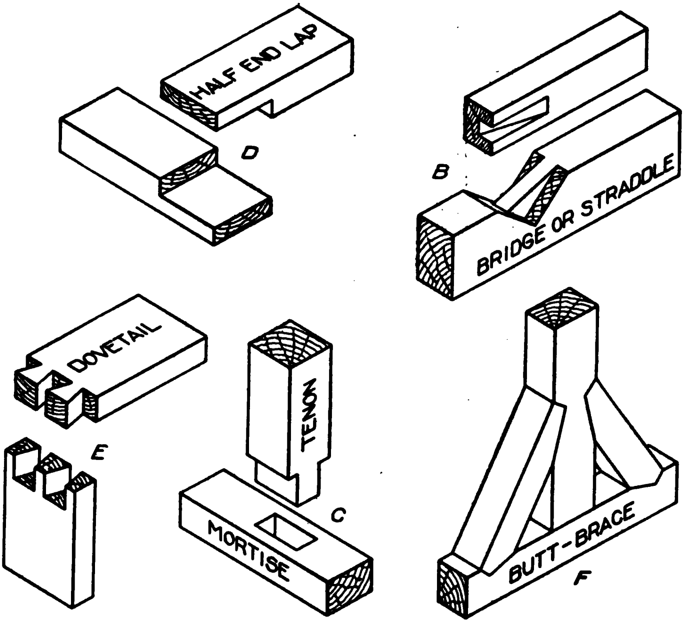


Fig. 91

be so located as to give the greatest service. Fig. 90 shows an isometric representation of a framing detail, and, although not in accordance with the orthographic working drawing, shows to an untrained imagination

a better idea of the construction. Note the dimensions between members, size of stock and joinery. The plate, at A, for the second floor, is usually set *in* an inch in the studding. This is called a *gained* joint.

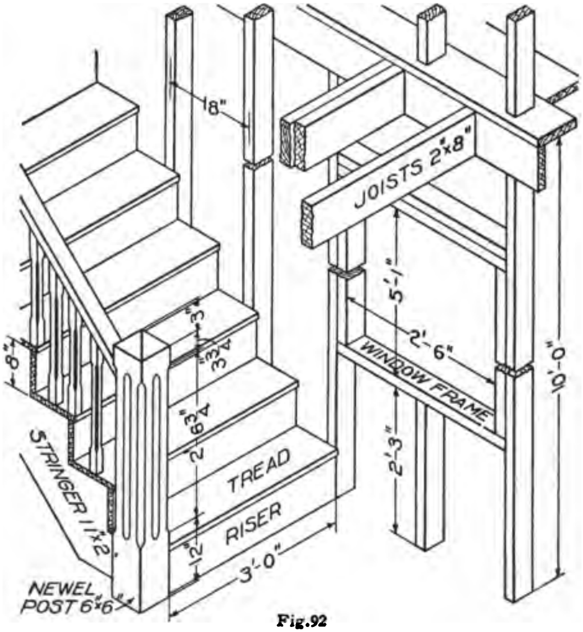


Fig.92

Other forms of joints are *miter, tongue-and-groove, tenon-and-mortise* (C), *dovetail* (E), *half-end lap* (D), *bridge* (B), *butt* (F) and *open tenon with key,* each having a special purpose for its use. Fig. 91.

Problem 1.—Make an assembled drawing—plan and

front elevation—of the framing details suggested in Fig. 90, and dimension properly. Scale 1½ inch = 1 foot.

Problem 2.—As in Problem 1, make a drawing of the stair detail. Risers, 7″; tread, 10″ wide. Balusters 2″ square and space equal to the width of baluster. Fig. 92.

Problem 3.—Make a working drawing of the forms of joints used in joining represented in the illustration. Scale, half-size. Dimension. Use stock sizes of materials. Fig. 91.

Problem 4.—Make a floor plan of your home, a barn or school-room, and show all appointments. Scale ⅛″ to the foot. Small details are usually drawn larger or to full scale.

Problem 5.—An examination in high-school drawing included the following: Make to scale ¼″ to 1′ an architect's plan for the upper five-room flat in a modern three-story building. Show by the customary architectural conventions all that is necessary and usual. Outside dimension 22′ 6″x36′.

CHAPTER VIII

PATTERN-WORKSHOP DRAWINGS

ONE of the most useful applications of the working drawing is the laying out of patterns, or developments. The theory of such a drawing is found in the study of Descriptive Geometry—a science which all architects and engineers are required to know something about and which is extremely useful to draftsmen, although often avoided.

A thorough knowledge of the principles of patternmaking enables the tinsmith or sheet-metal worker to lay out very complicated patterns in a very simple geometric manner and thereby save time and material to all concerned. Cutting a pattern so as to be as economical as possible, requires foresight which the usual patternmaker fails to exercise. Tin-plate scraps often may be used to as good or better advantage than new sheets, if conservatively and thoughtfully cut, and in all kinds of work stock should be ordered so that a minimum amount of waste is left.

A pattern is a plane surface representing the unfolded sides of an object equal to the *perimeter* of its *right section*, the width equal to the altitude of the object, or, rather, the true length of its lateral surface.

Develop the surface of a cylinder or prism upon a sheet of bristol paper, allowing 3/8 inch for lap. Glue the lap and fasten together for a facsimile of the original. Add bottom and top.

In most cases, in beginning a problem, it is only necessary to draw the plan and front elevation plus an auxiliary sectional view to show the true size of the cut section. From any of the illustrations, Figs. 93 and

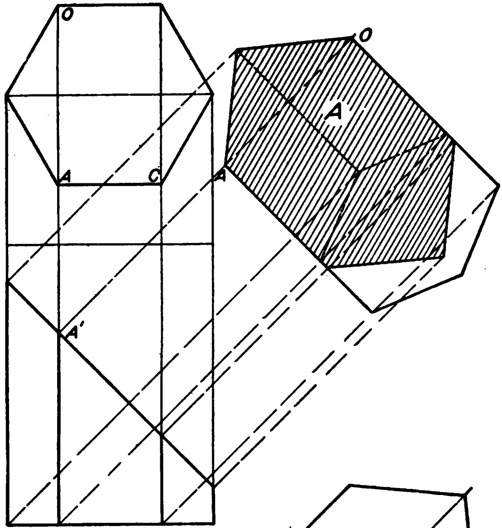


Fig. 93

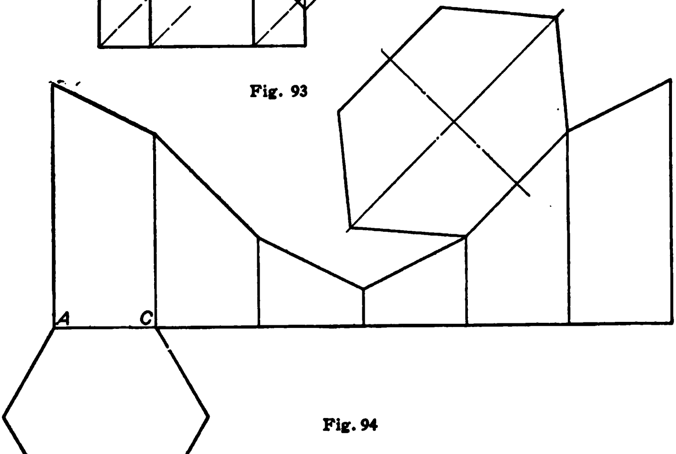


Fig. 94

95, it will be seen that the object is projected up into the plane of the paper to obtain the auxiliary view. After the pattern is drawn it is transferred from the

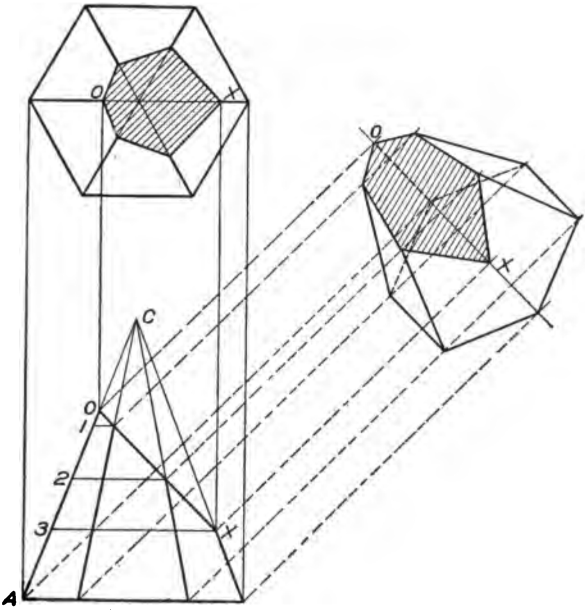


Fig. 95

manila or bristol paper to the metal by pricking points with a sharp punch along the contour of the pattern, due allowance being made for lap and seam. The double edge shown on the development of the quart measure is for the lock seam shown at A, Fig. 100.

PARALLEL METHOD

Problem 1.—A truncated hexagonal prism is to be developed as shown in Figs. 93 and 94. Use any suitable dimensions. Construction: Draw the plan and

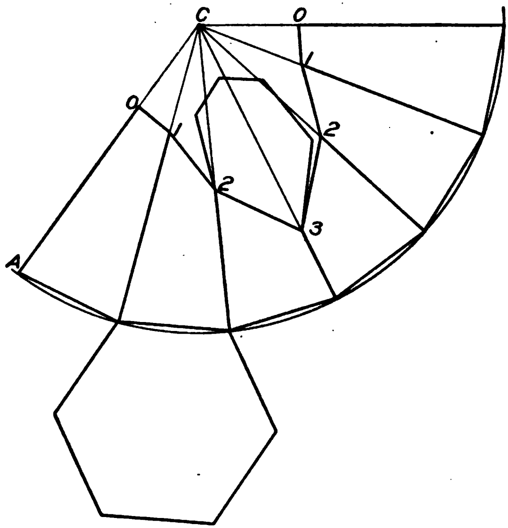


Fig. 96

elevation, also sectional view, as at A. The width of the section and base is the same as the depth of the prism transferred from the plan view. In the "layout" the various heights of the linear elements of the prism are laid off on corresponding parallels in a straight line, equal in length to the perimeter of the base.

Problem 2.—A truncated hexagonal pyramid is to be developed, as shown in Figs. 95 and 96, to suitable

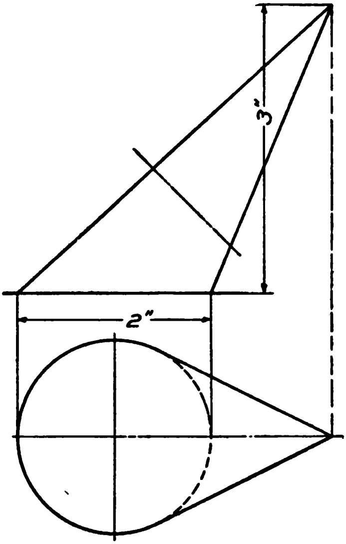


Fig. 97

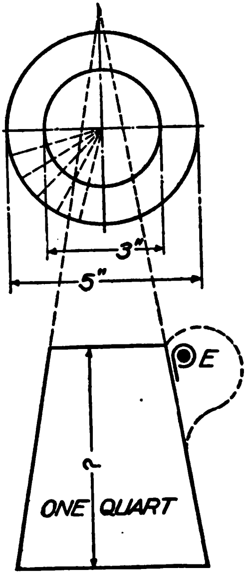


Fig. 99

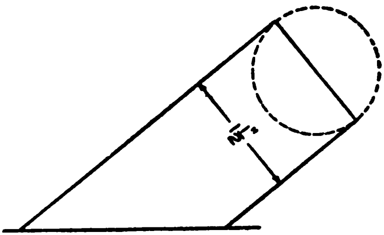


Fig. 98

dimensions. Construction: Obtain the projections and sectional view as in Problem 1. To obtain the development it is necessary to know the slant height of the pyramid. The exterior edges are parallel to the vertical plane; therefore, their true lengths must be seen at AC. With a compass set with AC as a radius,

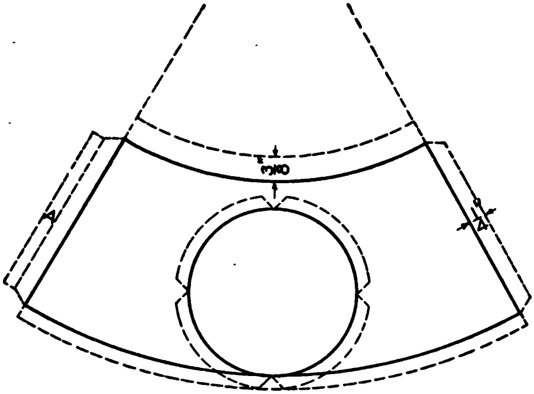


Fig. 100

describe an arc. Lay off the perimeter of the base on this arc and join all points with radial lines to the center of the arc C. Step off the true length of each cut element, 0, 1, 2, 3, shown projected on AC; then join as in Fig. 96. To complete the pattern add the section and the base.

Problem 3.—Develop a frustum of a rectangular pyramid, base 2″x1¼″ and altitude 3″.

Problem 4.—An irregular cone is projected in Fig. 97. Develop by radial lines as in Fig. 96, except that the true length of each element be found separately.

Problem 5.—Given the front elevation of a 1½" cylinder, Fig. 98, draw the plan and develop.

Problem 6.—Draw the pattern of a quart measure, Figs. 99 and 100, diameter of upper base 3", lower 5". Find the altitude. Note: This problem involves a principle of mensuration. Use either dry or liquid measure.

$$\frac{V}{\pi R^2} = A, \text{ or } \frac{V}{D^2\,(.7854)} = A,$$

where V = the volume, or solid contents and A = the altitude. This is approximate. To be exact, the formula should be stated as follows:

$$\left\{ a + b + \sqrt{ab} \right\} \frac{h}{3} = V,$$

when a = area of upper base.
b = area of lower base.
h = height or altitude.

There are 231 cubic inches in a liquid gallon and 2150.42 cubic inches in a bushel.

The problem here indicated is one of finding the altitude of the frustum of a cone. Substitute the known value of V, the volume, and solve for h as in any equation.

Fashion a suitable strip for a handle allowing ⅜" lap for edges. The illustration, E, Fig. 99, shows the lap over a wire at the top of the cup. A customary rule for lap is 4 × thickness of metal + twice the diameter of wire.

Problem 7.—An irregular triangular pyramid having an altitude of 4½", the sides of its base 2" or more in length and all lateral edges oblique to all planes of projection, has two lateral edges and base cut by a

sectional plane perpendicular to V and oblique to H. Draw the three orthographic views and the true size of the section. Develop. Figs. 101 and 102.

Problem 8.—An irregular oblique quadrilateral prism has a right section resembling Fig. 103. Use suitable dimensions. Its axis is inclined 30° to the right of its base, which is horizontal. A plane inclined 60° to the left of its base cuts all the lateral edges of the prism. Draw the three projections and the auxiliary or sectional view. Develop, adding the base and sectional view.

Problem 9.—Draw three views of a regular vertical pentagonal pyramid, with apex above the base. The rear edge of the base is inclined 15° to the vertical plane of projection, V, the left end of this edge to be nearest V. The diameter of the circumscribing circle of the base is 2″ and altitude 4″. The pyramid is cut by a plane perpendicular to V and at an angle of 60° to its base. Show the line of intersection in three views, make a sectional view, and develop either truncated part.

Problem 10.—A circular ventilator projects through a gambrel roof as shown in Fig. 104. Work out the line of its penetration with the roof planes. Develop the ventilator top and also the roof planes, showing the line of penetration. Scale 1″ = 1′ 0″.

Problem 11.—Develop a truncated right cone from the illustration. Fig. 105.

Note: Problems 7, 8, 9 and 10 are intended as test problems.

Any development of a geometric form is a mathematical process, and hence should receive some such consideration.

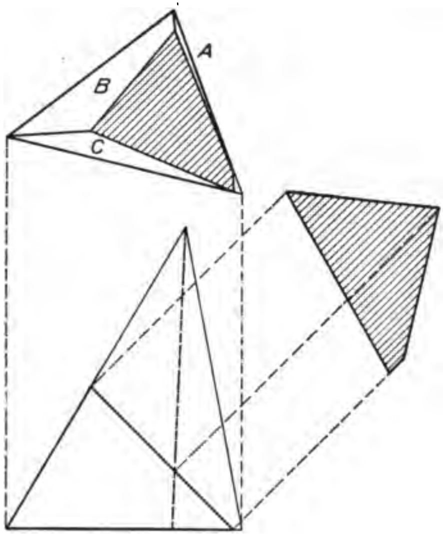


Fig. 101

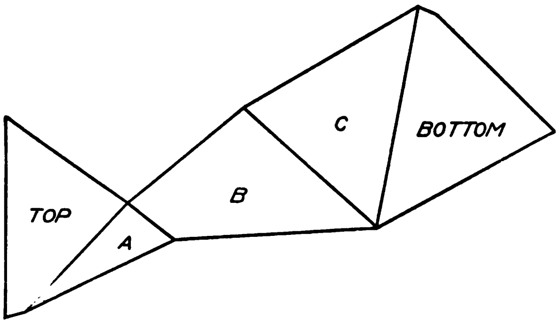


Fig. 102

The following formulas are self-evident and should be committed to memory:

$2\pi R$ = the circumference of a circle.

πR^2 = area of a circle.

$(\pi R^2)L$ = volume of a cylinder when L altitude.

$(2\pi R)L$ = lateral surface of cylinder.

$(\pi R^2)L/3$ = volume of cone.

$(2\pi R)S/2$ = lateral surface of a cone when S = slant height.

$6(XY/2)$ = area of a hexagon when X = one side of the polygon and Y = the apothem.

Note: The apothem of a polygon is the perpendicular distance from the center of a polygon to one of its sides.

$6(XY/2)L$ = volume of a hexagonal prism.

$6(XL)$ = lateral surface of a hexagonal prism.

$(2\pi R)D$ = lateral surface of a sphere when D = diameter.

Problem 12.—Develop a cylinder when R = ¾", L = 3".

Problem 13.—Develop a cone when R is given and the volume.

Problem 14.—The area of an octagon is 24 square inches. X = ¾". Develop full size.

Problem 15.—Y = ½", L = 2½". Develop.

Note: This problem involves a geometric construction of a hexagon without a circle before a development can be made. Using different data, originate and solve other problems.

Problem 16.—Fig. 106 shows the form of a sheet-metal hood for a forge. Scale, half size.

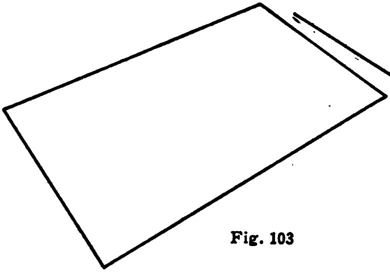


Fig. 103

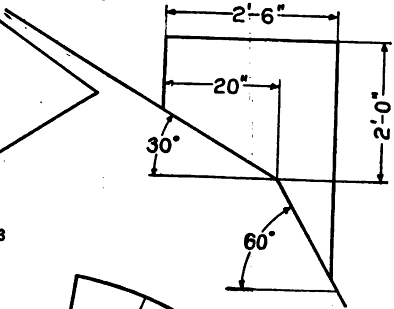


Fig. 104

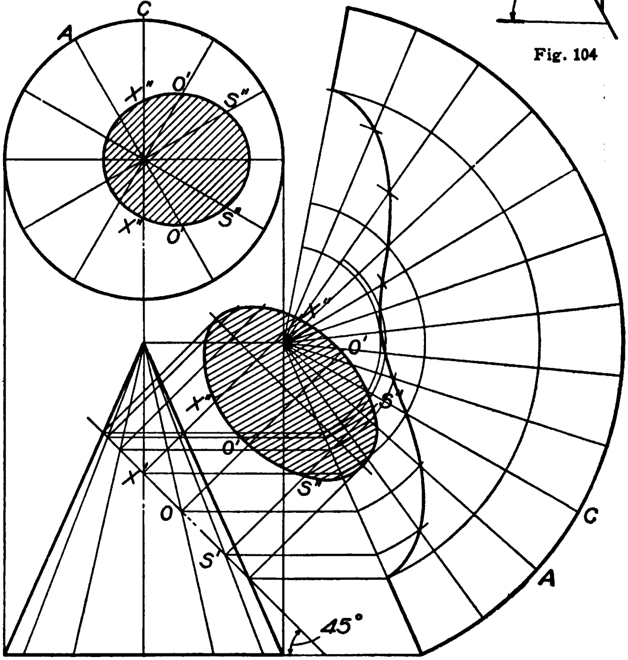


Fig. 105

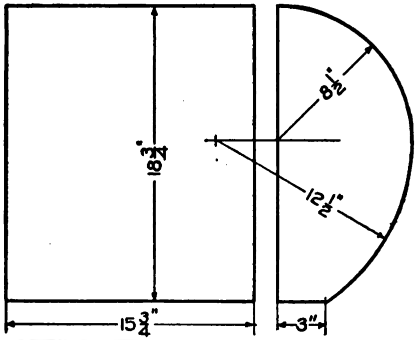


Fig. 106

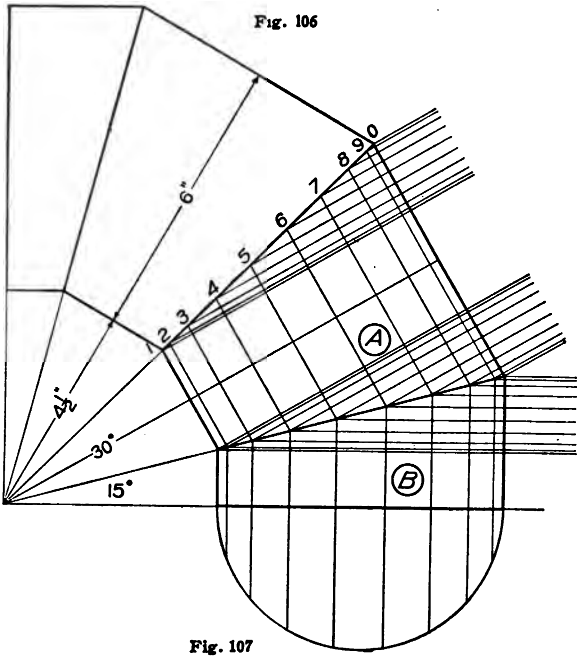


Fig. 107

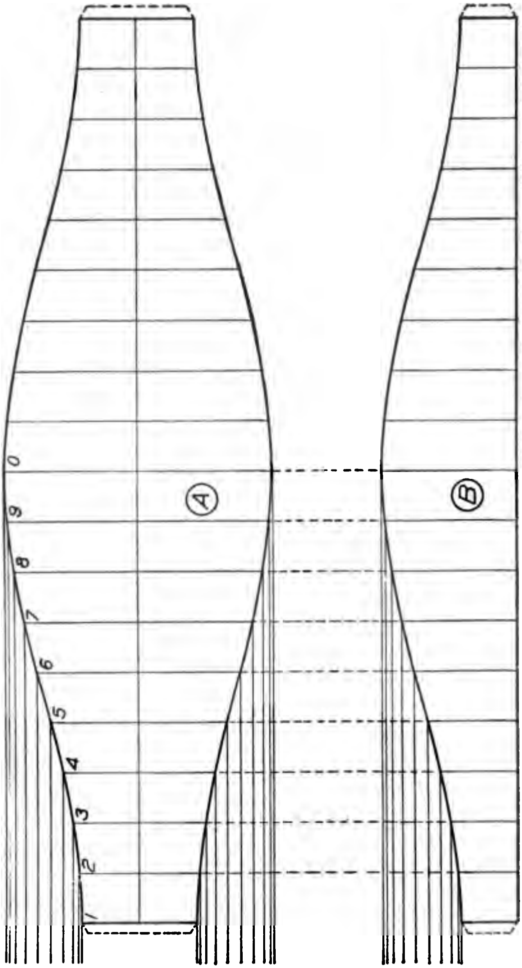


Fig. 103

Problem 17.—Fig. 107 gives the front elevation of of 6″ stove pipe elbow, and Fig. 108 the development of a large and small section.

Problem 18.—Develop a 3″ sphere by the "orange peel" method. Fig. 109.

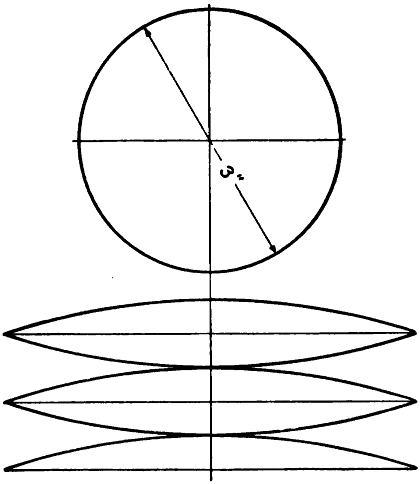


Fig. 109

Problem 19.—Secure a good model of a funnel and draw out the pattern.

METHOD OF TRIANGLES

Problem 20.—Tapering ventilator collar. Many problems are impossible to develop by either method previously referred to, on account of their surfaces being warped. A warped surface cannot be laid out

geometrically, but it can be constructed approximately by means of triangles. The mold-board of a plow, "cowcatcher" of a locomotive, marine ventilator funnels, grain elevator spouts, a cow's horn, stacks, coal

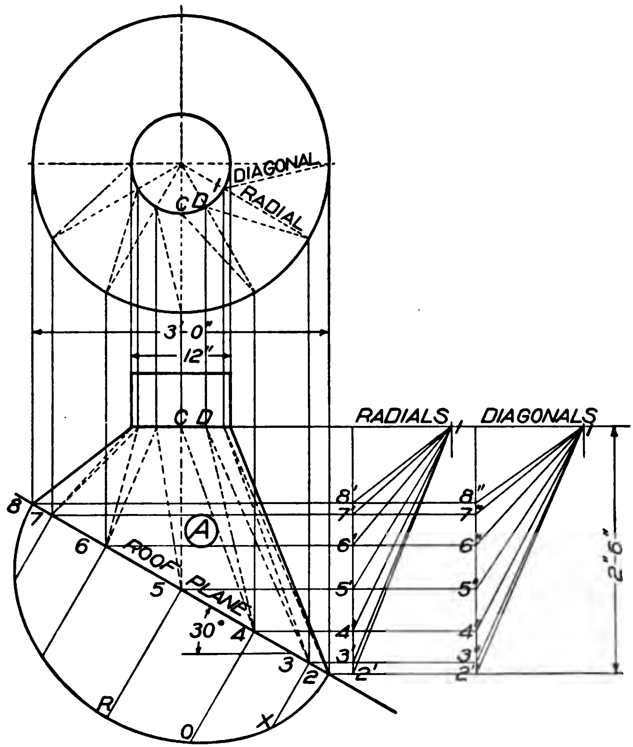


Fig. 110

scuttles, footballs, and similar objects with irregular surfaces, are non-developable except by the approximate method above referred to. Construction: Lay off on the projections of the figure small triangles at regular intervals, determine their true size and lay ad-

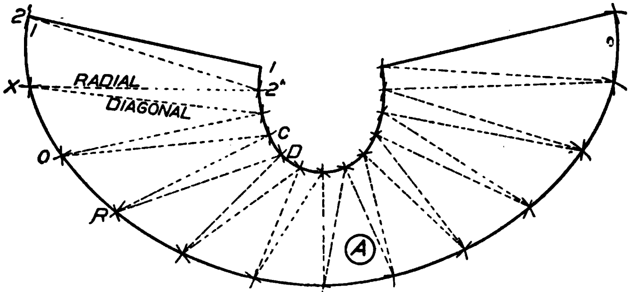


Fig. 111

jacent to each other. This will constitute, as near as may be done, a working pattern. The base of each triangle is shown in the plan view, the altitude in the elevation. Fig. 110.

The hypotenuse of any right-angle triangle is easily determined when two of its sides are known. Development (Fig. 111): Lay off at any convenient place a radial, and for our purpose we will select the longest. At the lower end strike an arc equal to X-2 on the sectional view of the roof plane. With center at 2′, Fig. 111, and radius equal to the length of the first diagonal 1-2″, intersect the small arc 1-2″. Small arcs are equal to C-D. With center 2″ and radius 1-3 strike arc at X, then lay off second radial on either side of first radial, 1-2′. Repeat until all radials and diagonals have been used. Any warp surface may be developed in this manner.

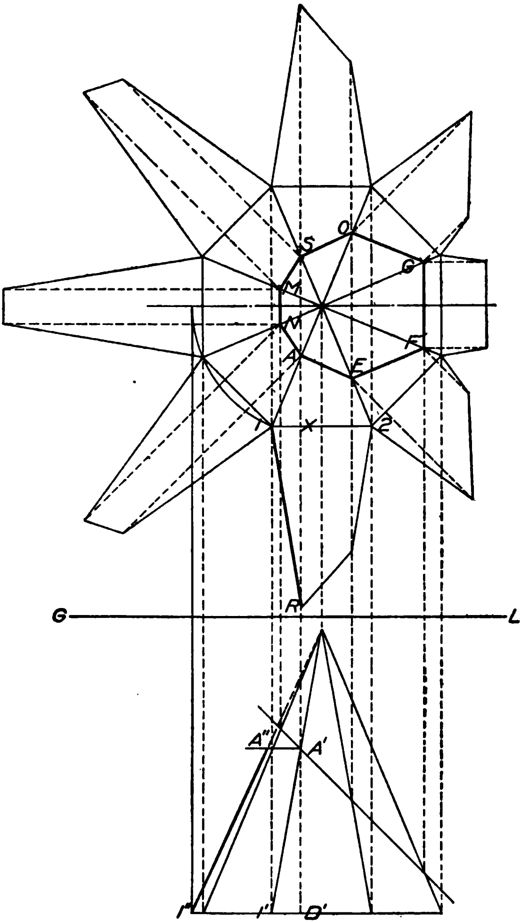


Fig. 112

Problem 21.—Select a kitchen utensil which primarily must be laid out in pattern and make a development to scale. A dust-pan, roasting-pan, coffee-urn, colander or coal scuttle is suggested. Use any method

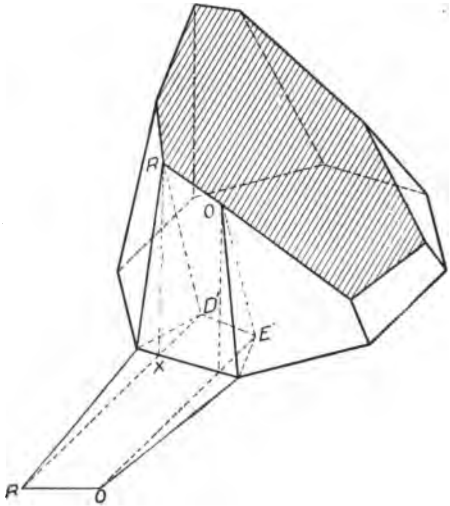


Fig. 113

or combination of methods, but be sure to determine whether the surface can be developed, or is warped, or any part thereof. Develop a truncated, irregular cone, Fig. 97 (page 95), by triangles.

DEVELOPMENT BY REVOLUTION

Fig. 112. This method is not so practical, but is more mathematically exact than former methods referred to and is especially used to verify the radial

line method. In geometry we are told that a point revolves about an axis in a plane perpendicular to the axis. This holds true here, for the upper edges of the truncated section revolve in perpendicular paths to the lower edge of the base. The length of the radius of revolution is determined by constructing a right-angle triangle one side of which always equals the distance AX from the horizontal projection of the point A to the axis 1-2 in the plan,—the other of the perpendicular altitude, A′-D′, from the vertical projection to the plane of the base. The hypotenuse must equal RX. Connect 1-R, which is the true length of 1-A. This interesting exercise should be repeated until every step is clear. It is a graphical explanation of the same process in mensuration.

A second method, and closely related to the above, is to find the true length of each edge of the truncated pyramid and lay off these true lengths on the paths of revolution as drawn through the upper points A, E, F, G, etc., from points of the base X, to R. The method of finding the true length of 1′-A′ is shown by revolving 1-A parallel to GL and projecting to the base of the pyramid 1′, then moving to its revolved position and A′ also. The true length of 1′-A′ is now shown at 1″-A″. Fig. 113 is an isometric illustration of the above.

CHAPTER IX

PENETRATIONS

WHEN one object intersects or penetrates another, the line of intersection of the two is defined where they meet. To determine the pattern this line must always be geometrically located, as in Fig. 114, and herein lies, very frequently, a difficult problem if the subject of working drawings and projections has not been thoroughly mastered.

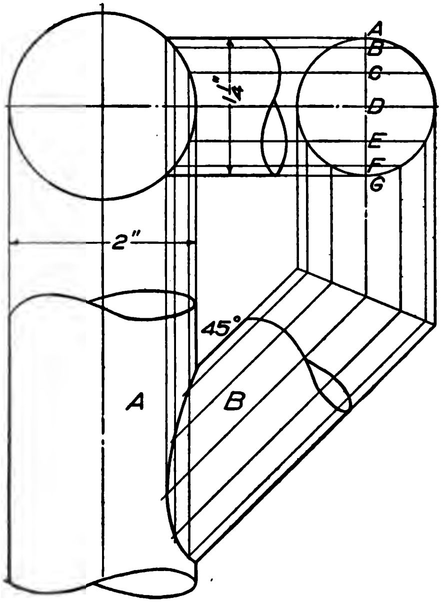


Fig. 114

DEVELOPMENT BY PARALLEL PLANES

Problem 1.—Fig. 114 is an illustration of two intersecting pipes. First, draw the plan and front elevation. Conceive a series of parallel planes, A, B, C, D, E, F, G, cutting through both pipes and parallel to

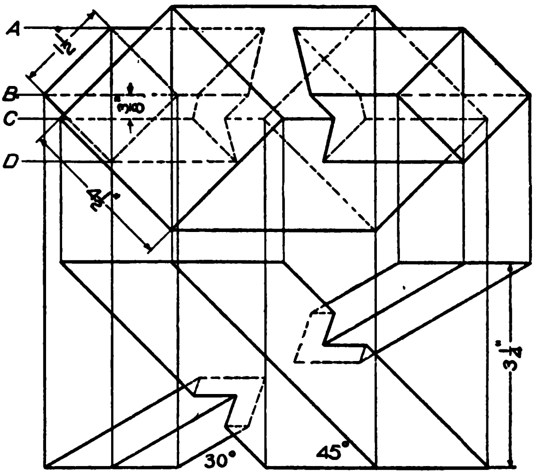


Fig. 115

the front elevation. Each plane cuts two elements from each pipe, and all of the four elements lie in the same plane. In this case, two elements of pipe B penetrate one element of pipe A. Determine the projections of each element thus cut, and where they intersect is a point of penetration.

To develop either A or B, lay out the perimeter of a right section, the height of the pattern being equiva-

lent to the length of the elements from the end of the cylinder to the line of penetration.

A right sectional view shows the shortest possible circumference or perimeter of the object and is determined by a plane perpendicular to the axis of the figure.

Problem 2.—Fig. 115 represents a small rhombic prism penetrating a larger one, the top of each being a square in plan. Establish the lines of penetration in both plan and elevation, lay out the development of the smaller prism and develop the *hole* in the larger. Locate the line of penetration in the development of the smaller prism. A, B, C, D are planes passed parallel to the vertical plane. Find the projections of each element cut from both prisms. Where they meet, or intersect, determines the line of penetration, for each *cut element* lies in the same auxiliary plane. Number each point, or letter with some familiar symbol. When objects are oblique to H or V pass a plane to determine the true perimeter of the right section. The trace of such a plane in this problem must be perpendicular to the lateral edges of either prism. The development must be made from this sectional line and in a similar manner to the layout of the hexagonal prism, Problem 1, Fig. 94 (page 92).

Problem 3.—As in problems 1 and 2, find the line of penetration of a right cylinder with a right cone. Fig. 116. Pass horizontal planes. Axes of both figures lie in the same plane. Use appropriate dimensions. Note that each plane cuts a circle from the cone and two elements from the cylinder. This is an illustration of a conical hopper connecting with a cylindrical pipe, or a gutter drip and rain-water pipe, as seen on many houses.

Problem 4.—A vertical pyramid 4″ high, with a triangular base, length of one side 2½″, one edge of base making 15° with V, is penetrated by a horizontal equilateral triangular prism, 4″ long and perimeter of 6¾″. One face is parallel to V and 1″ from the vertical axis

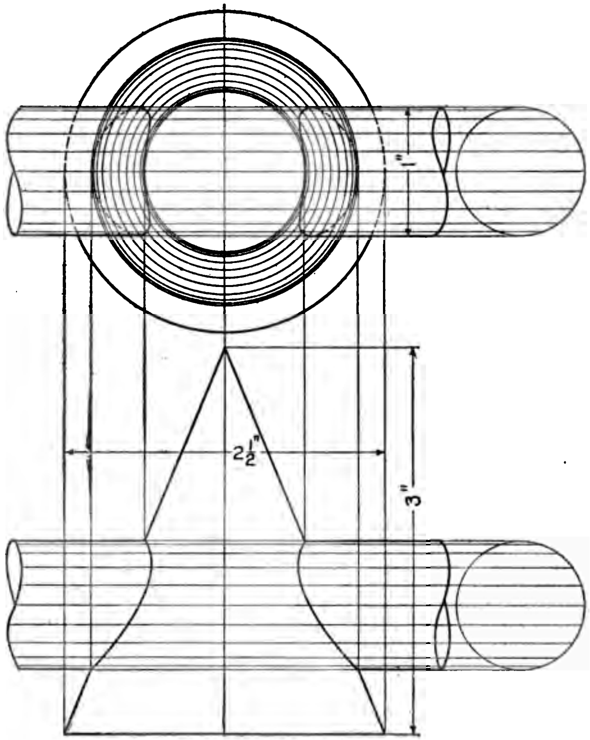


Fig. 116

of the pyramid. The axis of the prism is 1¾″ above the base. Draw three views full size, find the line of penetration and develop both objects. Figs. 117, 118 and 119.

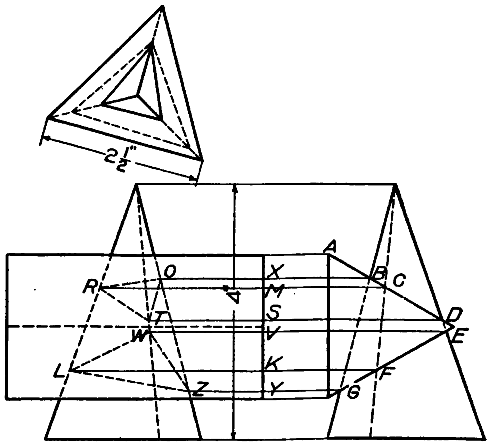


Fig. 117

Problem 5.—A conical steeple of a cylindrical tower is penetrated by the roof planes of a hip roof. Fig. 120. Find the line of penetration and lay out the developments of the conical roof and of the roof plane adjacent to the hip, showing the lines of penetration therein. Scale, ¾″ = 1′ 0″.

After drawing the plan and elevation from the illustration, Fig. 120, pass planes M, N, O and P to determine the line of penetration. As each plane is // to the base of the cone it will cut a true circle from the cone, as shown in the plan. It will also cut a line

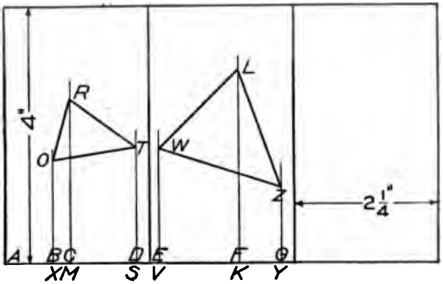


Fig. 118

from each roof plane parallel to the base of the hip roof. Where this element crosses the circle cut by the same plane is a point of penetration. A series of similarly acquired points will determine the line of intersection.

To develop a roof plane revolve the point O of the upper corner of the hip into the same plane as the base of the cone and the roof, by the triangle method. O

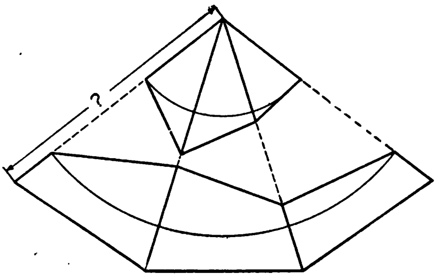


Fig. 119

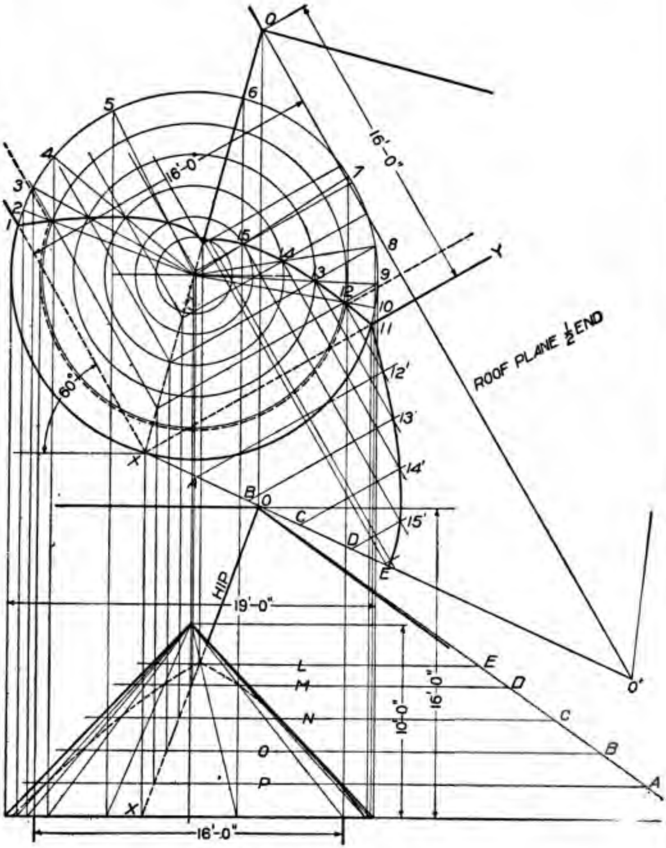

O
16'-0"
6
5
4
3
2
1
7
8
9
10
11
12
13
14
15
Y
16'-0"
60°
ROOF PLANE ½ END
12'
13'
14'
15'
X
A
B
O
C
D
E
HIP
19'-0"
L
M
N
O
P
E
D
C
B
A
O'
10'-0"
16'-0"
X
16'-0"

Fig. 120

moves in a plane ⊥ to the axis XY. Points 10, 11 and 12 move perpendicularly to the roof lines drawn through A, B and C. The development of the cone has been described. Fig. 121.

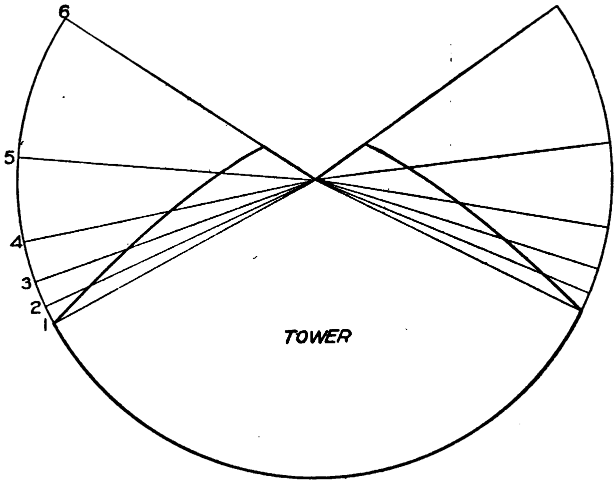


Fig. 121

Problem 6.—Develop the pattern for the base of a blower from dimensions given in Figs. 122 and 123. The right and left sides of this base are elliptical cylinders, that is, are not circular in cross section. The true size of the cross section cut by plane Tt′ is shown at X in the plan. This is the line of development, Tt′, Fig. 123. The lengths of each element can easily be laid out and the triangular faces added. Draw to suitable scale.

Problem 7.—Develop the slope sheet of a locomotive

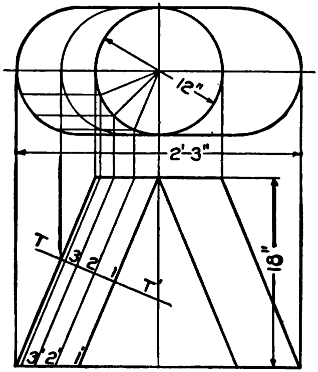


Fig. 122

as given in Fig. 124, one-half to be developed by triangulation. This is one of several practical problems to be derived from a study of the locomotive for purposes of developments. The steam-dome, sand-dome and smoke-stack are other illustrations of right cylinders penetrating the outside cover of the boiler and requiring templets or patterns.

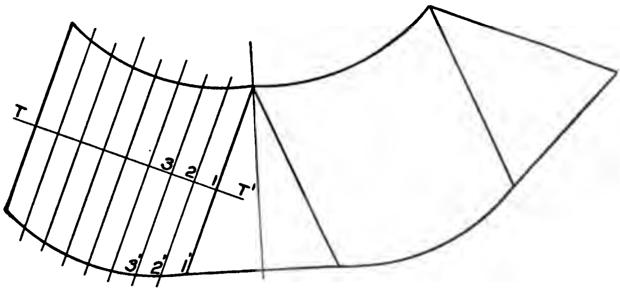


Fig. 123

Problem 8.—Draw the front elevation of the transition piece and develop by triangles or the method suggested. Fig. 125.

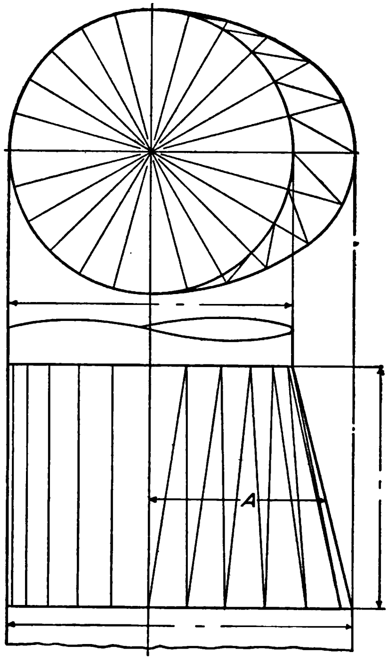


Fig. 124

Problem 9.—A regular vertical triangular prism, with a perimeter of 10½″ and 4″ altitude, has its front face inclined backward and to the left at 15°. A right

square prism of 6½" perimeter and 4" altitude penetrates the former. Axes of both solids intersect at their center points. Develop both objects.

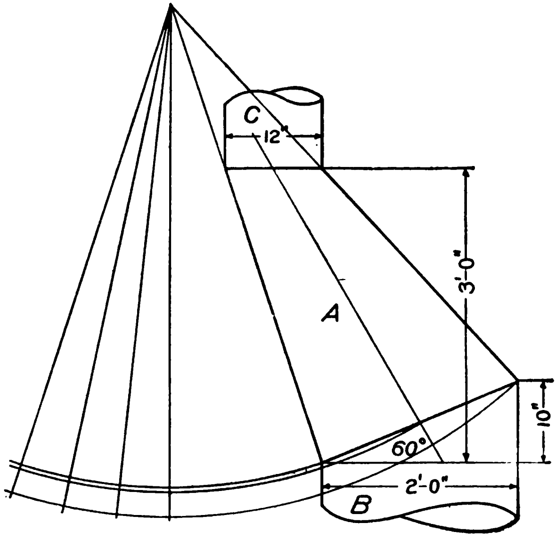


Fig. 125

CHAPTER X

ISOMETRIC WORKING DRAWING

AN ISOMETRIC drawing is generally conceded to be a pictorial or perspective representation, and for practical purposes it has come to be eminently useful to the artisan in clarifying hidden constructions. Among draftsmen it has supplemented the freehand perspective sketch on account of the comparative ease with which the picture is made by the instruments.

The few principles of isometric drawing may briefly be summed up as follows:

a. All *vertical* edges in the object are vertical in the drawing, as in freehand.

b. All horizontal edges, representing right angles

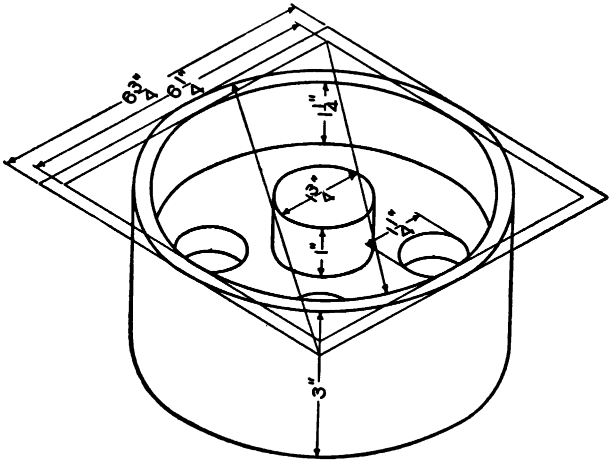


Fig. 126

orthographically, make 30° to the horizontal in the isometric construction.

c. Non-isometric lines of edges making other than right angles must be laid off orthographically first and then transferred to the isometric drawing. This distorts the *true* length of non-isometric lines, but does not mar the pictorial effect.

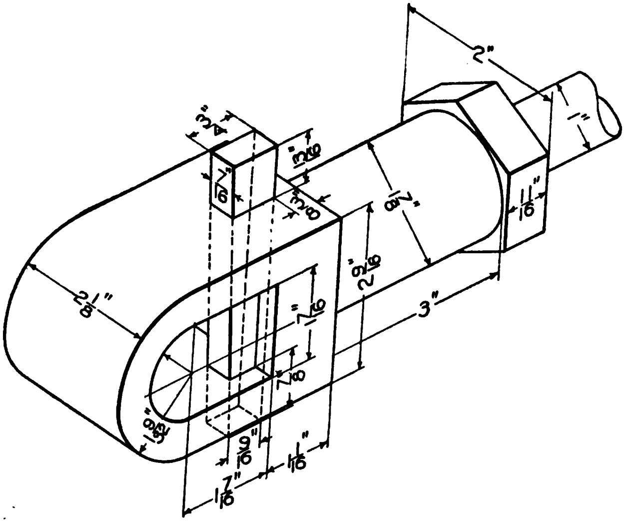


Fig. 127

d. Surfaces, not lying in the same plane, are established from center-isometric axes.

e. Isometric circles are drawn within isometric squares of the same diameter as the given circle. Elliptic or irregular curves are constructed flat, then transferred. Fig. 126.

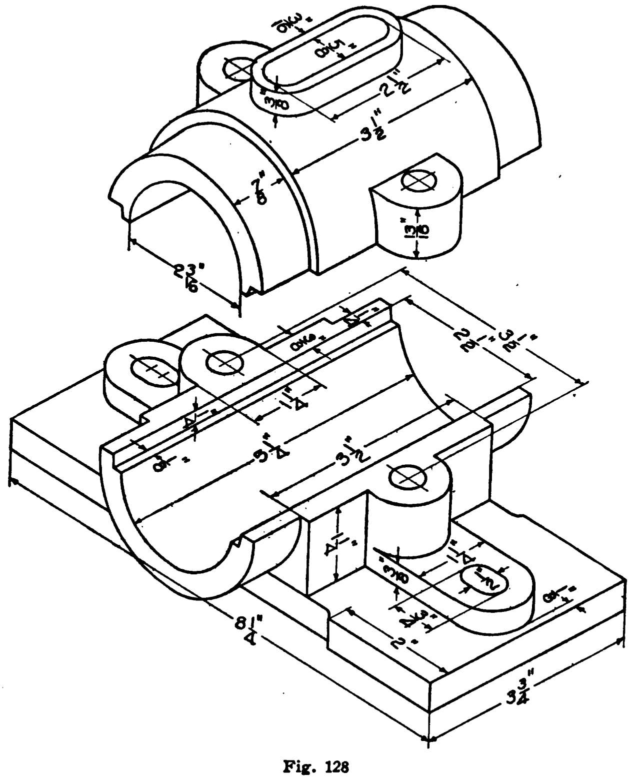


Fig. 128

f. Isometric workshop drawings are dimensioned. Dimensions must be placed parallel to the isometric lines. Fig. 127.

g. The usual custom of shading an isometric drawing is to accent the edges separating light surfaces from dark, assuming the light to come from the left at an angle of 45°. A better method, and one which enhances the pictorial effect, is to shade all edges which are nearest the observer's eye. This tends to lift the drawing of the object from the paper and relieve the unnatural effect of the isometric construction. Fig. 127 is an illustration of the stub end of a connecting rod and exemplifies the second method described above. There are many draftsmen, however, who do not shade any drawings. The true purpose of shading is to make the drawing more attractive, but aside from this it has no value.

h. Invisible lines are seldom shown in isometric drawings except where irregular lines are hidden by regular surfaces and the information desired can in no other way be shown.

The illustrations in the text have largely been unshaded *isometric* drawings of objects used in the classroom.

Problem 1.—Make an isometric drawing of a chalk or cigar box with the lid open. Scale, half size. No dimensions.

Problem 2.—Select a good-sized spool. Draw in isometric. Scale, double size. No dimensions.

Problem 3.—Copy the exercise of the connecting rod, Fig. 127. Scale, full size. Dimension.

Problem 4.—Figures 128 and 129 represent the base

and cap of a pattern for a pillow-block bearing. Scale, full size. Dimension.

Problem 5.—The teacher's desk to suitable scale. Do not show invisible lines. Dimension. Substitute a book-case.

Problem 6.—A mission chair. Look for non-isometric lines. Dimension, and draw to suitable scale.

Problem 7.—A shaft-hanger. Scale, half size. Isometric.

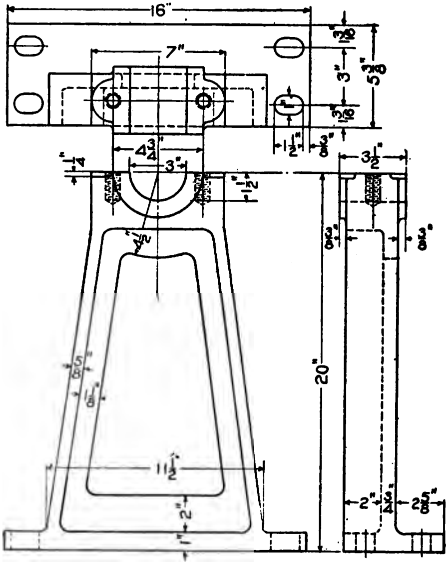


Fig. 129

CHAPTER XI

A SUGGESTED COURSE FOR HIGH SCHOOLS

Group 1. Geometric Exercises

Problem 1.—Bisect a given right line and arc.

Problem 2.—Erect $\perp$s to a given line (any method).

Problem 3.—Draw parallel lines (two methods).

Problem 4.—Divide a given line into proportional parts.

Problem 5.—Construct tangents to a given arc of any radius. (Fillet.)

Problem 6.—Duplicate and bisect a given angle.

Problem 7.—Without triangles construct $\angle$s of 30°, 60°, 75°, 45°, 22°-30′, 37°-30′.

Problem 8.—By triangles only divide a semicircle into angles of 15°.

Problem 9.—Rectify a quadrant of a circle (two methods). Approximate.

Problem 10.—Triangles (trilium—trefoil).

a. Right angle (rise, run and pitch of a gable roof rafter) $x^2+y^2=z^2$.

To find the distance across an unknown area—a stream, lake or park; also to find altitude of a tree.

b. Equilateral. (Isometric square—Gothic arch).

c. Isosceles.

d. Scalene.

Query: How find the area of any triangle?

What is the sum of all angles of a triangle?

Problem 11. Square (bolthead plan—swastika—syringa).

Problem 12.—Polygons (pansy, violet—crystals).

a. Pentagon—star (three methods).

b. Hexagon—bolthead plan (two methods)—star.

c. Heptagon.

d. Octagon—taboret top.

e. Combination of *a, b, c, d* on a given side of 1″.

Prove all polygons by the formula $\frac{2n-4\times 90}{n}$ when $n =$ the number of sides of polygon. Use the protractor to verify.

Problem 13.—Circles:

a. Three circles within an equilateral triangle.

b. Draw circles tangent to each other and the given circle, within or without.

c. Gothic arch.

d. A circle tangent to a given circle and line.

e. A circle tangent to two given circles which are not tangent to each other. Note: The smallest circle is not acceptable.

**f.* A shaft 1½″ in diameter rotates within a ball-bearing consisting of twelve tempered steel balls. Make a drawing showing size of balls required.

g. Four circles within a square.

h. Maltese cross.

i. Geometric circular borders.

j. Moldings—cavetto, cyma, reversa, cyma recta, ogee, scotia.

Problem 14.—Ellipses and elliptic curves (conic sections—ecliptic).

a. Focal method; circle method.

b. Trammel method.

c. Five-point elliptic arch.

d. Greek, Persian and Gothic arches.
e. Elliptic cam.
**f.* The path of a point on a connecting rod in one revolution.
**g.* Cycloid. } (Gear teeth.)
**h.* Epicycloid.
i. Hypocycloid.
**j.* Parabola. } (Conic sections.)
**k.* Hyperbola.

Problem 15.—Spirals:
a. Archimedean spiral of one or more whorls.
b. Ionic volute (Ionic capital).
**c.* Heart plate cam (sewing-machine bobbin-winder).
**d.* Involute (gear teeth).
**e.* Helix-screw thread, clutch coupling.

Biographical.—From the encyclopedia read the biographies of Archimedes, Pythagoras, Euclid, Vignola.

It is intended that the number of problems should be arranged on the plate according to the local conditions of the class-room. Large plates, say 15″x20″, are more comprehensive but require less time for execution in proportion to smaller plates. Such problems in this outline which have not been given in the text are not essential, but, if desired, may be obtained from the instructor. Those who expect to study design are not required to complete the entire course of mechanical drawing. The problems marked by (*) may be omitted in this group.

Group 2. Projections.

I. Working drawings.
1. Three views of a cylinder.
2. Three views of a prism.

3. Two views of a plinth—one view given.
4. Three views of a pyramid.
5. Hexagonal nut.
6. Crank arm.
7. Small pedestal bearing.
8. Taboret or stand.
9. Coat-hanger.
10. Knife-box.
11. Tailstock.
12. Tool-rest.

Note: The first eight problems are not to be dimensioned. Substitutes may be selected for these objects where and when these are not available or advisable. Problems 8 to 15 are to be dimensioned carefully. Models are to be preferred to a drawing at the beginning of this course, so that the absolute relation of object to drawing will be established as early as possible.

13. Detailed working drawings from machine parts.
14. Working drawings from isometric blueprints.
15. Working drawings from sketches (freehand).

II. Revolution—Axes of symmetry.

1. Draw three views of a prism, plinth or pyramid.
2. Draw three views of No. 1 when revolved about a vertical axis 30°, contra-clockwise.
3. From No. 2 revolve object about side axis through 30° to the left.
4. From No. 1 revolve the object forward about a front axis 20°.
5. From No. 2 revolve the object backward about a front axis 25°.
6. From No. 5, 30° about a side axis, to the right.
7. From No. 4, 15° about a vertical axis.
8. From No. 5, 15° to the right about a side axis.

Several plates involving the modified positions of geometric figures should be drawn that the theory of projections may be perfectly clear. Learn the three laws of revolution given.

III. The point, line and plane. (For advanced students.) Draw in both first and third angles.

1. Find H and V projections of a point 1½" in front of V and 2¼" above H. Two inches below H and 1½" behind V. Always open the first angle.

2. Draw the projections of a line which is // to the H and V planes, 1¾" above H and 2" in front of V.

3. Draw two views of a line oblique to H and // to V; oblique to V and // to H; oblique to H and V.

4. Find the true length of lines in No. 3. What is the difference between the *projected* length and the *true* length of a line?

5. Pass a plane (*a*) // to H; (*b*) // to V; (*c*) // to P; (*d*) ⊥ to H, and any ∠ with V; (*e*) ⊥ to (V) and any ∠ with H and P.

6. Find the intersection of *a* and *b*, also *d* and *c* in 5.

IV. Development of surfaces for patterns of sheet-metal and tinsmithing.

1. Parallel lines. Cylinders, prisms, etc.
2. Radial lines. Cones, pyramids, etc.
3. Method of triangles. Warped surfaces.
4. Method of revolution. Frustums and truncations.
5. Method of parallel planes; oblique planes. Penetrations.

V. Penetrations with developments included.

VI. Shades and shadows.

VII. Mechanical perspective.

REFERENCE VOCABULARY

FOR the benefit of those who, for the first time, may meet new terms and expressions in this manual, the following vocabulary, with definitions, is appended:

Altitude. Vertical height.

Angle. Space between two intersecting lines.

Apex. Point where converging lines meet.

Apices. More than one apex.

Arc. Any part of the circumference of a circle.

Area. Surface in units of measurement.

Bisect. To cut in two equal parts.

Bisector. A line which bisects.

Chord. The line connecting any two points of an arc of a circle.

Circumference. The boundary of a circle.

Circumscribe. To draw around.

Convention. Customary method or symbol used in producing a drawing.

Decagon. Figure of ten sides and ten angles.

Degree. One 360th part of a circle.

Diameter. The distance measured across the center of a circle or a line drawn through the center terminating in the circumference.

Element. A part which goes to make up the whole.

Elevation. A view of an object looking at the front or side.

Elliptical. Pertaining to the shape of an ellipse.

Equilateral. Equal-sided.

Frustum. Remaining portion of a cone or pyramid when the top has been removed parallel to the base.

Hemisphere. Half a sphere.

Heptagon. Figure of seven sides and seven angles.

Hexagon. Figure of six sides and six angles.

Horizontal. Parallel to the horizon.

Hypotenuse (spelled also *Hypothenuse*). The diagonal distance between opposite angles of a rectangle or the side opposite the right angle.

Isometric. Of equal measurement.

Isosceles Triangle. A triangle with two sides of equal length and base angles equal.

Lateral. Side.

Line. That which has length only.

Median. Line drawn from the vertex of an angle to the middle point of the opposite side of a triangle.

Nonagon. Figure of nine sides and nine angles.

Octagon. Figure of eight sides and eight angles.

Orthographic. Derived from two Greek words, *orthos*, straight and *graph*, to write. Hence applied to a straight-line drawing determined by projection on H, V and P.

Parallel. Lines or planes are said to be parallel when all points of one are equally distant from all points of another.

Parallelogram. A four-sided figure with opposite sides parallel and of equal length.

Pentagon. Figure of five sides and five angles.

Perimeter. The distance measured around.

Perpendicular. Any line at right angles to another.

Pi (π). A Greek letter used as a convenient symbol to express the relation between diameter and circumference. $\pi = 3.1416$. The diameter of a circle $\times \pi =$ circumference.

Plan. A view looking down upon the top.

Plane. A surface with length and width and no thickness.

Plinth. A prism whose height is less than any one of its other dimensions.

Point. That which has position only.

Polygon. A plane figure bounded by four or more sides.

Prism. A figure bounded by rectangular faces, two of which are parallel.

Project. To point toward.

Pyramid. A solid with triangular faces converging to a common vertex.

Quadrant. The fourth part of a circle.

Quadrilateral. A four-sided polygon.

Radius. Half the diameter.

Radii. The plural form of *radius*.

Rectangle. A plane figure with four right angles of 90° each.

Rectify. To make straight or right.

Rectilinear. Pertaining to right or straight lines.

Rotate. To roll.

Scalene Triangle. A triangle all sides of which are unequal in length.

Section. A view determined by a cutting plane.

Sector. A radial division of a circle or the space between two radial elements.

Segment. The space between the chord and arc of a circle.

Semi-circle. Half a circle.

Sphere. Ball or globe. A solid with all points of the surface equally distant from a point within, called the center.

Tangent. To lie adjacent at a single point.

Triangle. A three-sided figure.

Trisect. To cut into three equal parts.

Truncate. To cut off.

Vertex. A common point of several converging lines.

Vertical. Always straight "up and down."

DEFINITIONS OF SYMBOLS

$2\pi R$ Circumference of a circle when $R =$ radius.

πR^2 Area of a circle when $R =$ radius.

$\perp$ Perpendicular.

$\parallel$ Parallel.

$=$ Means "equals" or "is equal to".

$\measuredangle$ Angles.

$\times$ Intersecting, or multiplied by, as the case n ..

$\therefore$ Therefore.

∟ Right angle. Two intersecting lines making 90° to each other.

$\angle$ Acute angle. Two intersecting lines less than 90° to each other.

Obtuse angle. Two intersecting lines more than 90° to each other.

H Horizontal.

V Vertical.

P Profile.

GL Ground line.

VL Vertical line.

Errata:

Page 18 Line 4- Should read: From any point "B" on the given line and a radius equal to BX describe arc.

Page 18 Line 6- "any" should read "same".

Page 24 Line 2- BX should read BD.

Page 40 Fig. 38- A1 should read A3 and vice versa.

Page 42 Fig. 41- Should read Fig. 42 and vice versa.

Page 46 Line 4- "pitch" should read "base" and omit "PC".

Page 46 Line 8- Omit "PC".

Page 124 Problem 4- Should read "Figure 128 represents the base", etc.

Page 125 Problem 7- Should add "Fig. 129".

[illegible] a

[illegible]